US009104352B2

(12) **United States Patent**
Will et al.

(10) **Patent No.: US 9,104,352 B2**
(45) **Date of Patent: Aug. 11, 2015**

(54) **METHOD, APPARATUS AND SYSTEM FOR RENDERING AN OBJECT ON A PAGE**

(75) Inventors: **Alexander Will**, Randwick (AU); **Thomas Benjamin Sanjay Thomas**, Seattle, WA (US); **Delilah Gloria Slack-Smith**, Bardwell Park (AU); **Cuong Hung Robert Cao**, Revesby (AU); **Sheng Wu**, Chatswood (AU)

(73) Assignee: **Canon Kabushiki Kaisha**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 371 days.

(21) Appl. No.: **13/533,695**

(22) Filed: **Jun. 26, 2012**

(65) **Prior Publication Data**

US 2013/0003085 A1 Jan. 3, 2013

(30) **Foreign Application Priority Data**

Jun. 29, 2011 (AU) 2011203173

(51) **Int. Cl.**

G06K 15/00	(2006.01)
G06F 3/12	(2006.01)
G06T 11/60	(2006.01)
G06F 15/00	(2006.01)

(52) **U.S. Cl.**

CPC ***G06F 3/1211*** (2013.01); ***G06F 3/1245*** (2013.01); ***G06F 3/1285*** (2013.01); ***G06T 11/60*** (2013.01)

(58) **Field of Classification Search**

CPC G03G 15/6585; G03G 15/5058; G06K 15/02; G06K 15/1822; G06K 2215/0085; H04N 1/32; H04N 1/387; H04N 1/34; H04N 2201/0092; G06F 3/1211; G06F 3/1245; G06F 3/1285; G06T 11/60

USPC 358/1.1, 1.2, 1.5, 1.9, 2.1, 3.27, 1.18

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,515,675	B1	2/2003	Bourdev	
7,209,258	B1	4/2007	Markovic et al.	
7,262,782	B1	8/2007	Parenteau et al.	
7,692,652	B2	4/2010	Parenteau et al.	
2004/0249730	A1 *	12/2004	Morita et al.	705/30

* cited by examiner

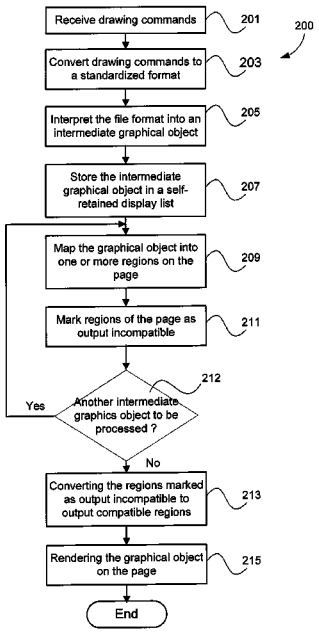
Primary Examiner — Thierry L Pham

(74) *Attorney, Agent, or Firm* — Canon USA Inc. IP Division

(57) **ABSTRACT**

A method of rendering a graphical object (e.g., **801**) on a page (**800**), is disclosed. A region of the page containing the graphical object (**801**) is marked as output incompatible based on the graphical object (**801**) being output incompatible. A bounding box comprising the marked region is determined. A proportion of a number of the regions marked as output incompatible are determined to a total number of regions in the bounding box. A further region within the bounding box is marked as output incompatible to increase the determined proportion above a threshold. The graphical object in the marked region and the further marked region is converted into an output compatible graphical object if the determined proportion is above the threshold. The output compatible graphical object is rendered.

4 Claims, 12 Drawing Sheets



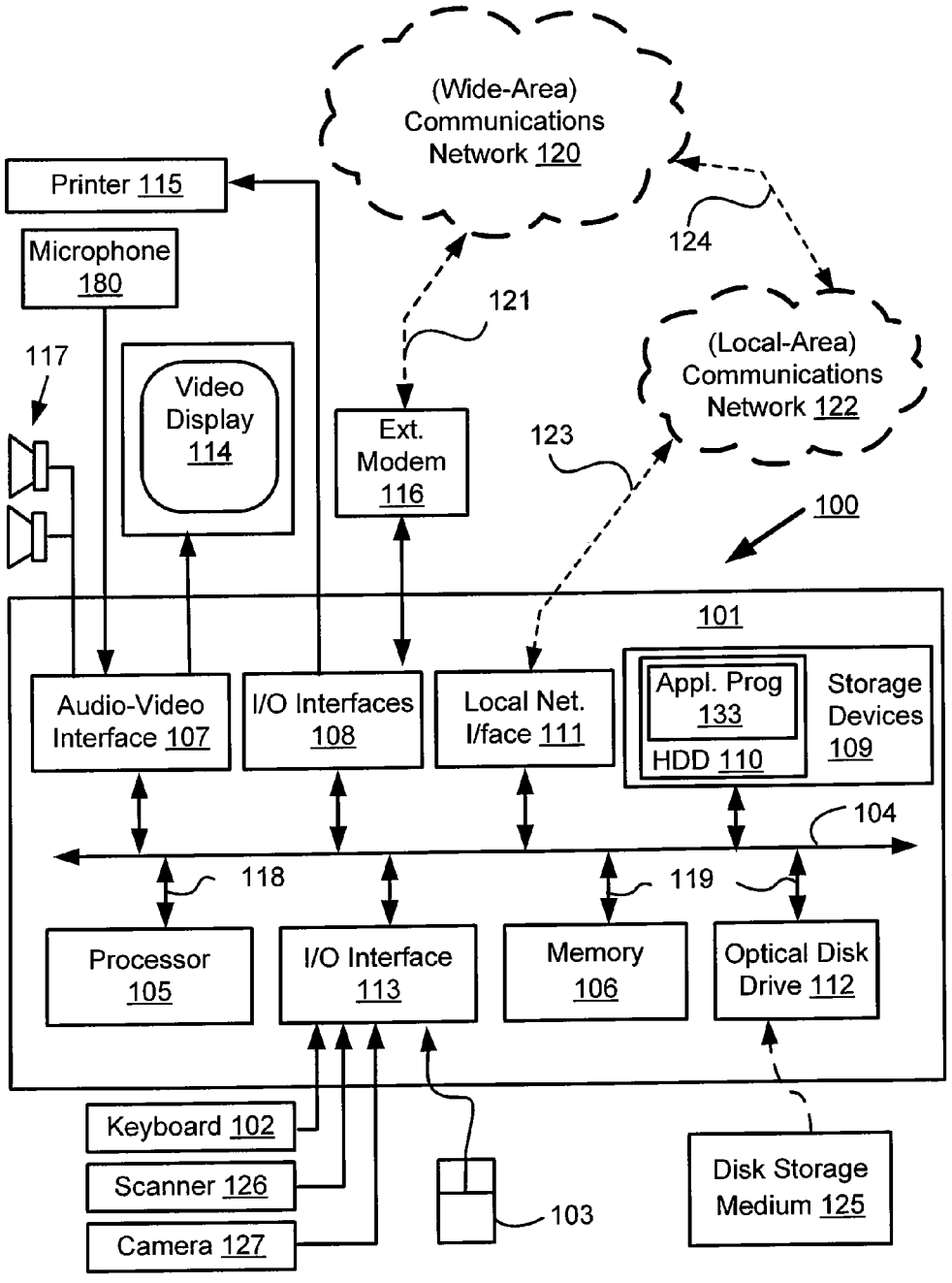

(Wide-Area) Communications Network 120
Printer 115
Microphone 180
117
Video Display 114
121
124
(Local-Area) Communications Network 122
Ext. Modem 116
123
100
101
Audio-Video Interface 107
I/O Interfaces 108
Local Net. I/face 111
Appl. Prog 133
HDD 110
Storage Devices 109
104
118
119
Processor 105
I/O Interface 113
Memory 106
Optical Disk Drive 112
Keyboard 102
Scanner 126
Camera 127
103
Disk Storage Medium 125

Fig. 1A

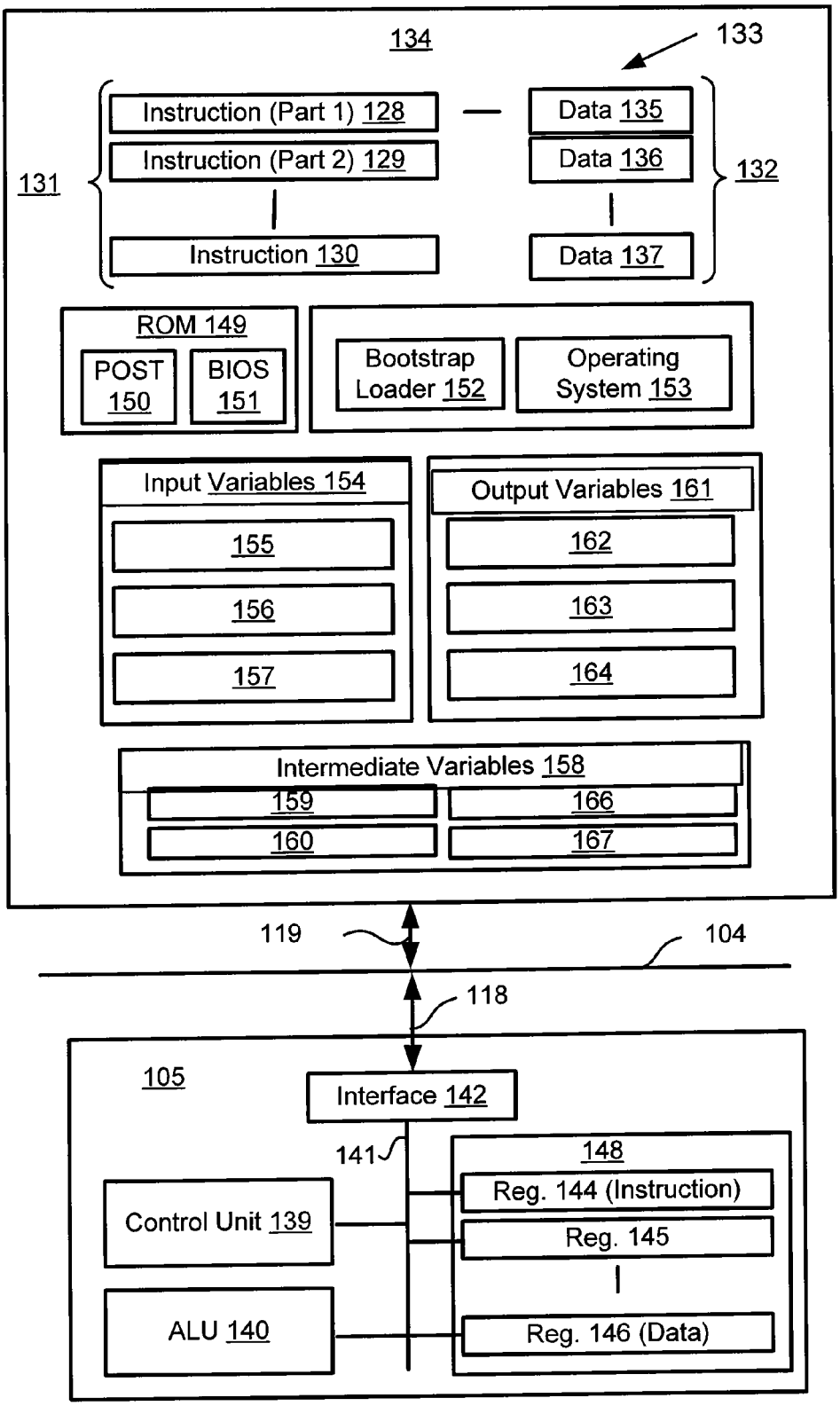

134
133
Instruction (Part 1) 128
Instruction (Part 2) 129
Instruction 130
131
Data 135
Data 136
Data 137
132
ROM 149
POST 150
BIOS 151
Bootstrap Loader 152
Operating System 153
Input Variables 154
155
156
157
Output Variables 161
162
163
164
Intermediate Variables 158
159
160
166
167
119
104
118
105
Interface 142
141
148
Reg. 144 (Instruction)
Reg. 145
Reg. 146 (Data)
Control Unit 139
ALU 140

Fig. 1B

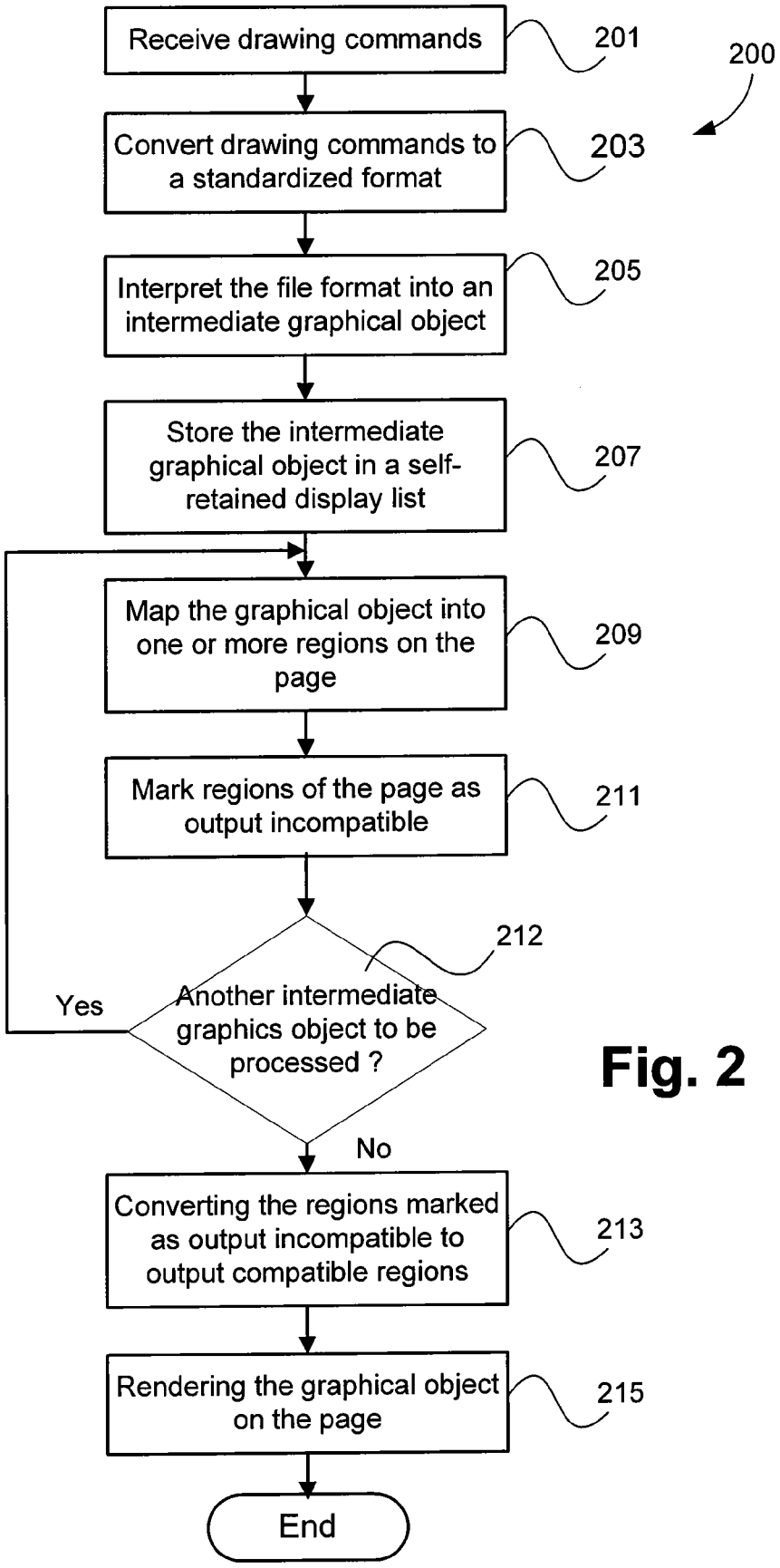

Receive drawing commands
201
200
Convert drawing commands to a standardized format
203
Interpret the file format into an intermediate graphical object
205
Store the intermediate graphical object in a self-retained display list
207
Map the graphical object into one or more regions on the page
209
Mark regions of the page as output incompatible
211
212
Another intermediate graphics object to be processed ?
Yes
No
Converting the regions marked as output incompatible to output compatible regions
213
Rendering the graphical object on the page
215
End

Fig. 2

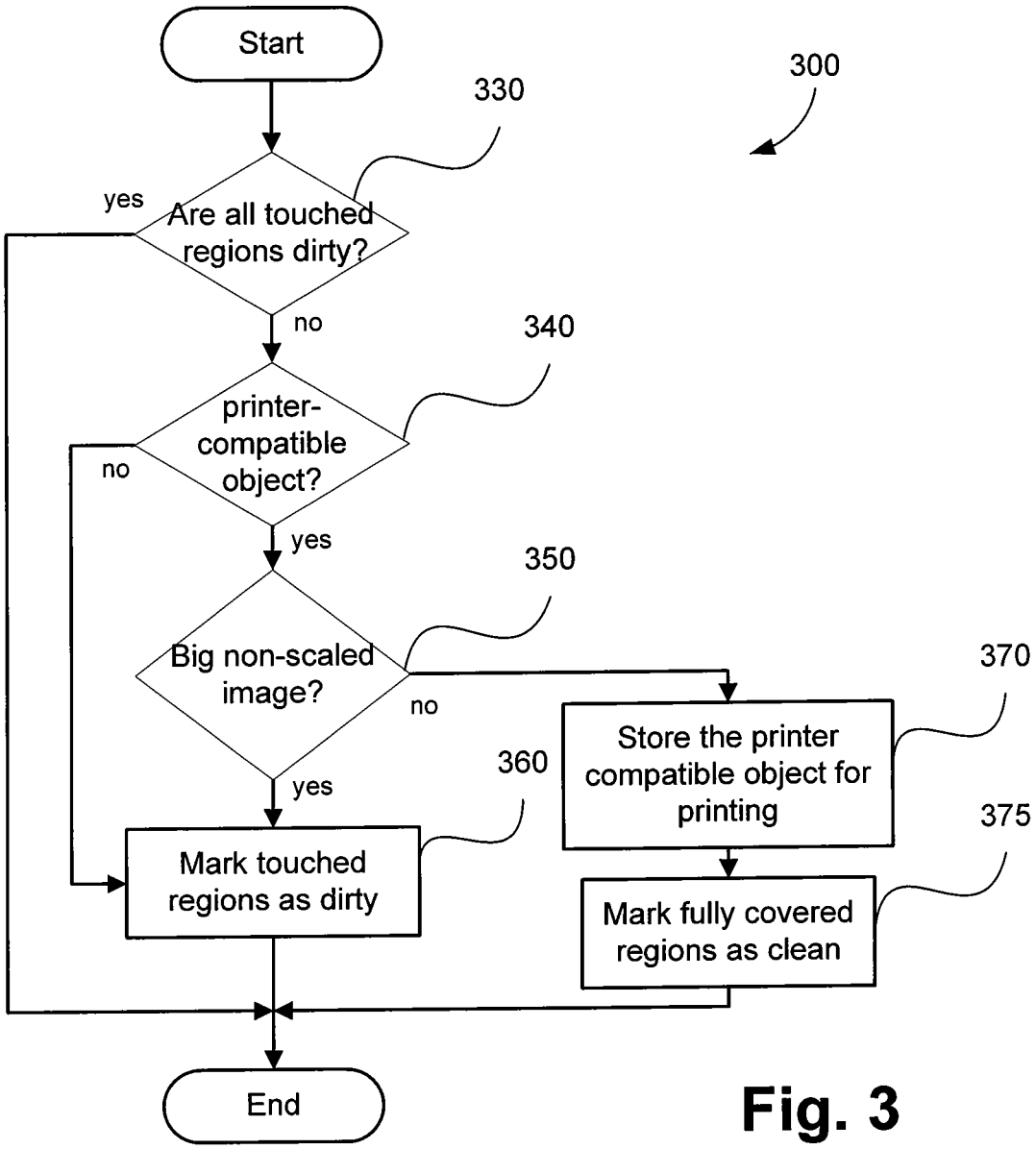

Start
300
330
Are all touched regions dirty?
yes
no
340
printer-compatible object?
no
yes
350
Big non-scaled image?
no
yes
370
Store the printer compatible object for printing
360
Mark touched regions as dirty
375
Mark fully covered regions as clean
End

Fig. 3

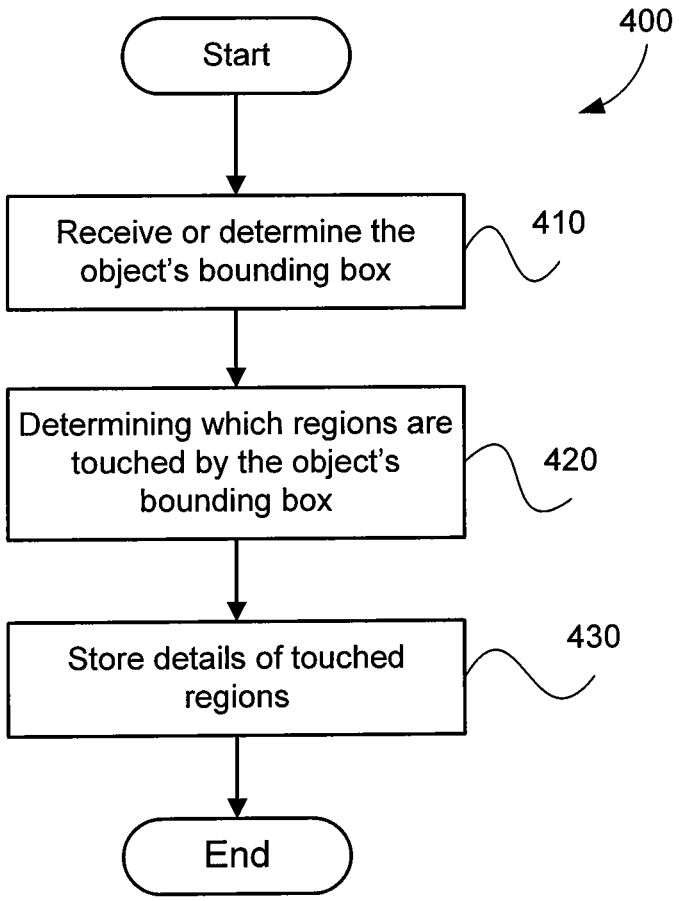

400
Start
Receive or determine the object's bounding box
410
Determining which regions are touched by the object's bounding box
420
Store details of touched regions
430
End

Fig. 4

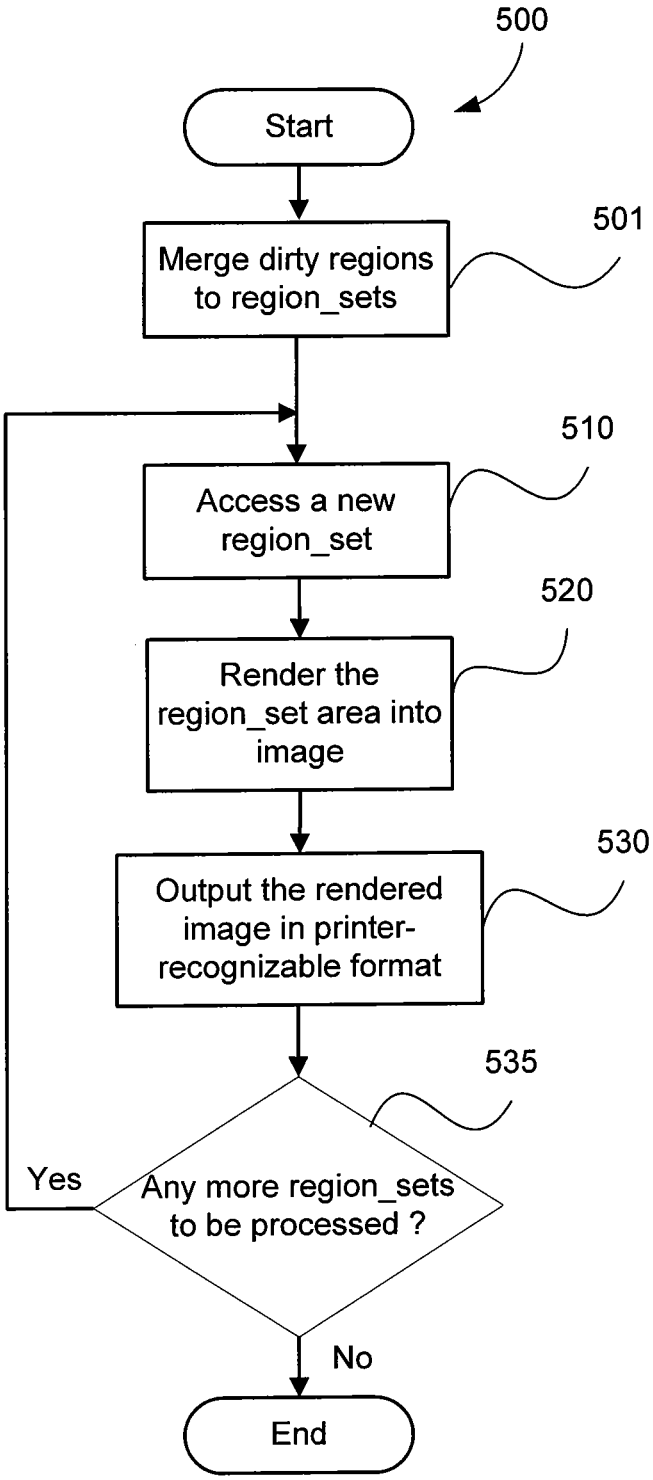

500
Start
501
Merge dirty regions to region_sets
510
Access a new region_set
520
Render the region_set area into image
530
Output the rendered image in printer-recognizable format
535
Any more region_sets to be processed ?
Yes
No
End

Fig. 5

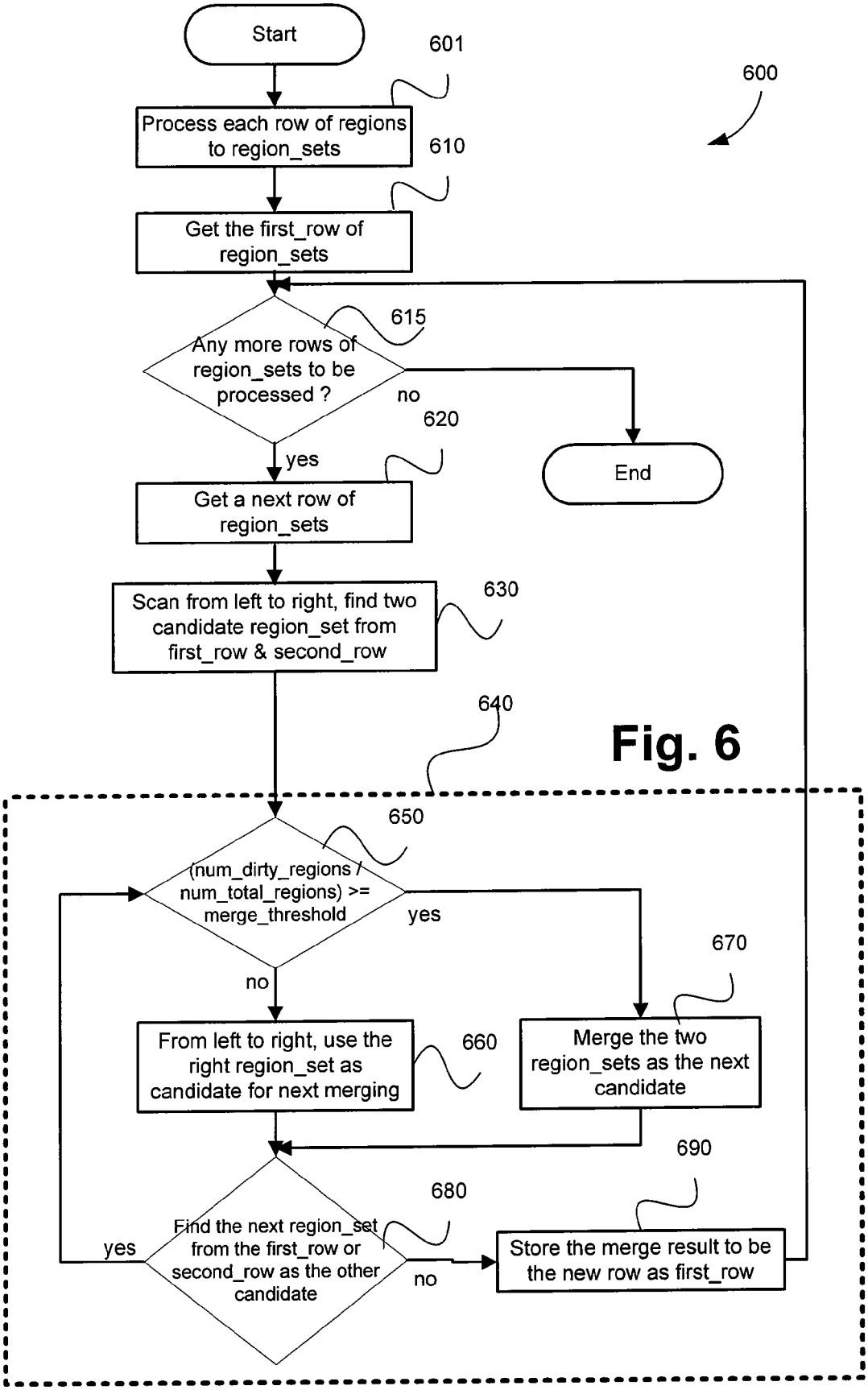

Start
601
600
Process each row of regions to region_sets
610
Get the first_row of region_sets
615
Any more rows of region_sets to be processed ?
no
620
yes
End
Get a next row of region_sets
Scan from left to right, find two candidate region_set from first_row & second_row
630
640
650
(num_dirty_regions / num_total_regions) >= merge_threshold
yes
670
no
From left to right, use the right region_set as candidate for next merging
660
Merge the two region_sets as the next candidate
690
680
Find the next region_set from the first_row or second_row as the other candidate
yes
Store the merge result to be the new row as first_row
no

Fig. 6

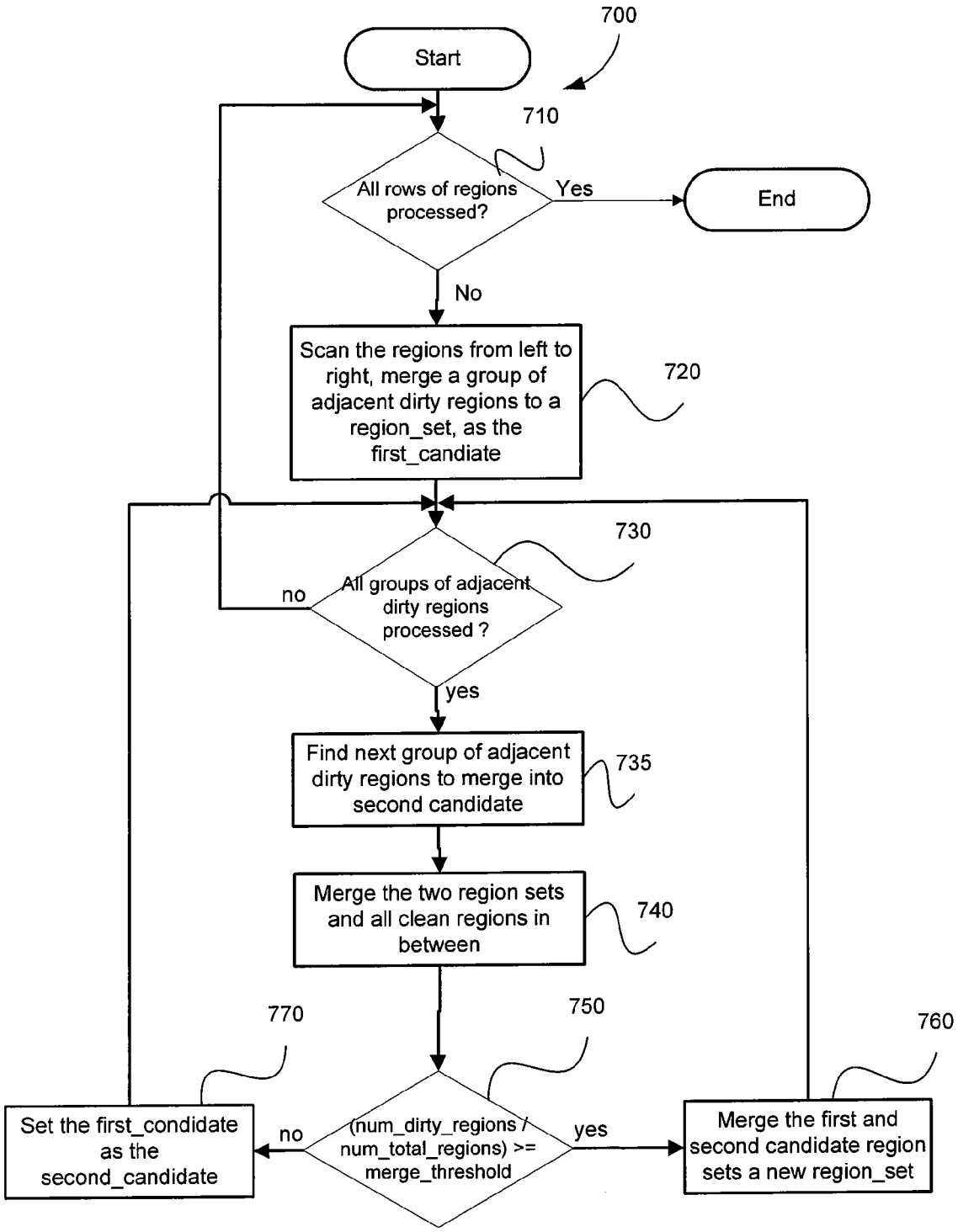

700
Start
710
All rows of regions processed?
Yes
End
No
Scan the regions from left to right, merge a group of adjacent dirty regions to a region_set, as the first_candiate
720
730
All groups of adjacent dirty regions processed ?
no
yes
Find next group of adjacent dirty regions to merge into second candidate
735
Merge the two region sets and all clean regions in between
740
770
750
760
Set the first_condidate as the second_candidate
no
(num_dirty_regions / num_total_regions) >= merge_threshold
yes
Merge the first and second candidate region sets a new region_set

Fig. 7

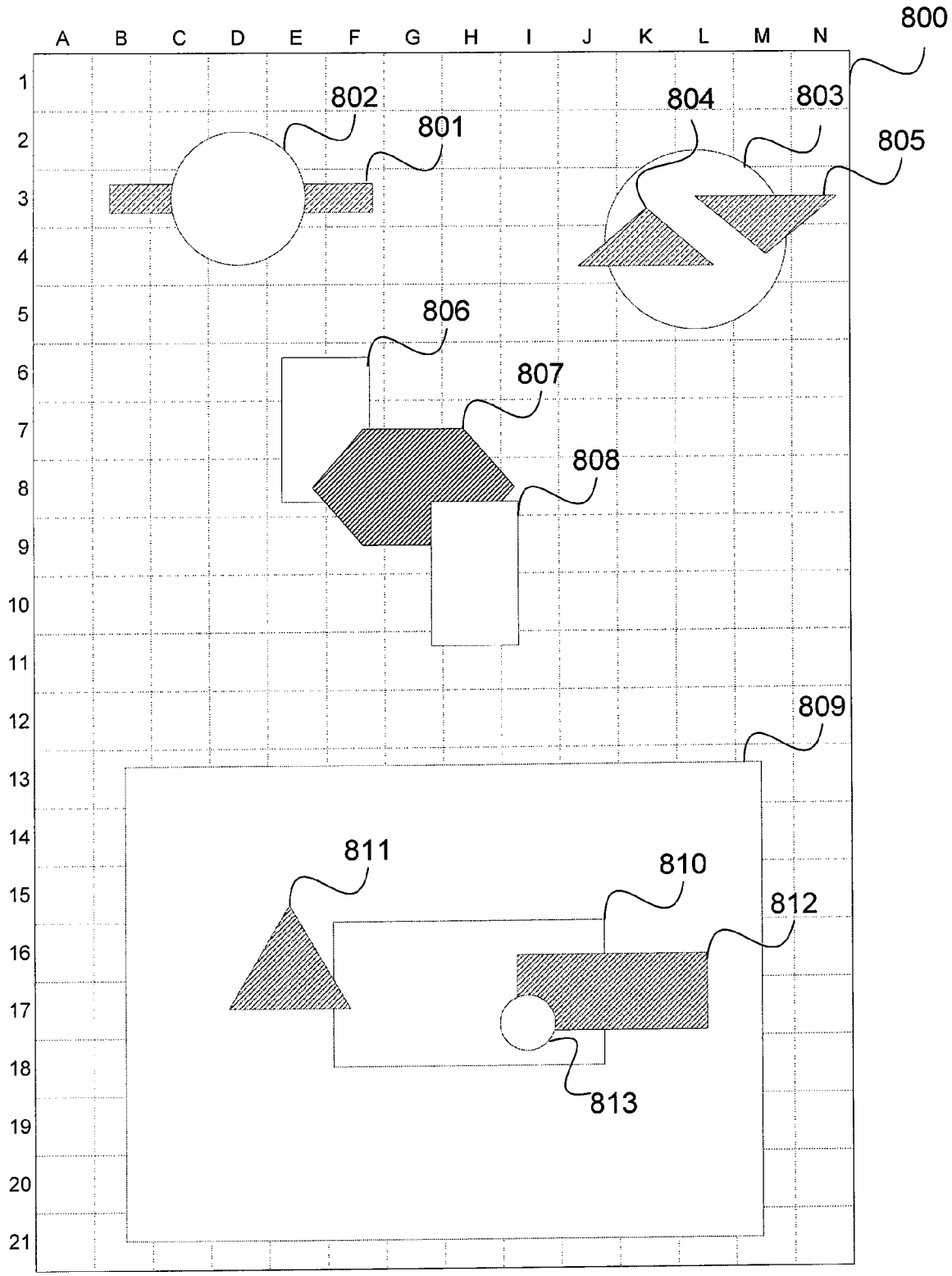

800
A B C D E F G H I J K L M N
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
802
801
804
803
805
806
807
808
809
811
810
812
813

Fig. 8A

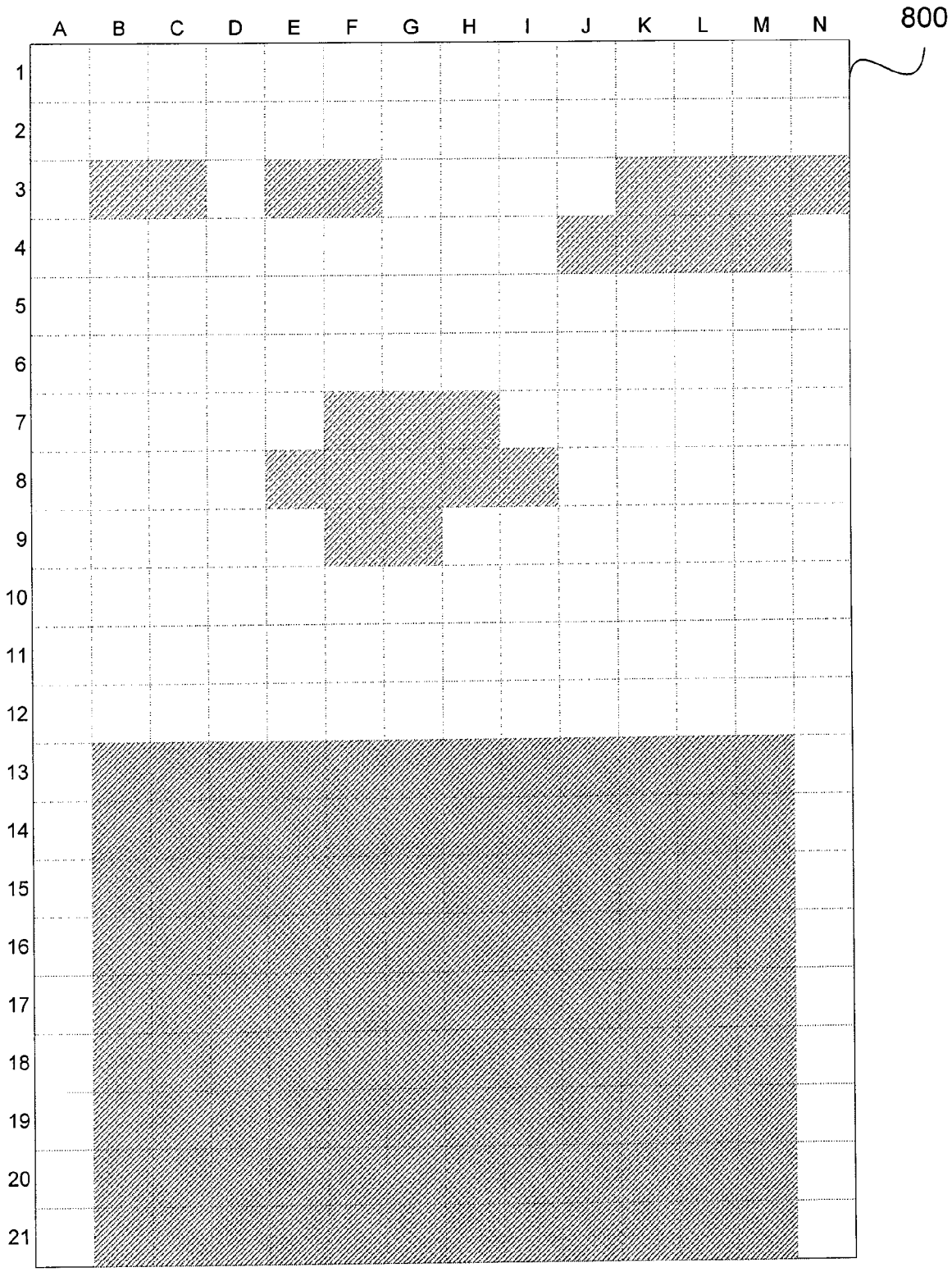

800
A B C D E F G H I J K L M N
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

Fig. 8B

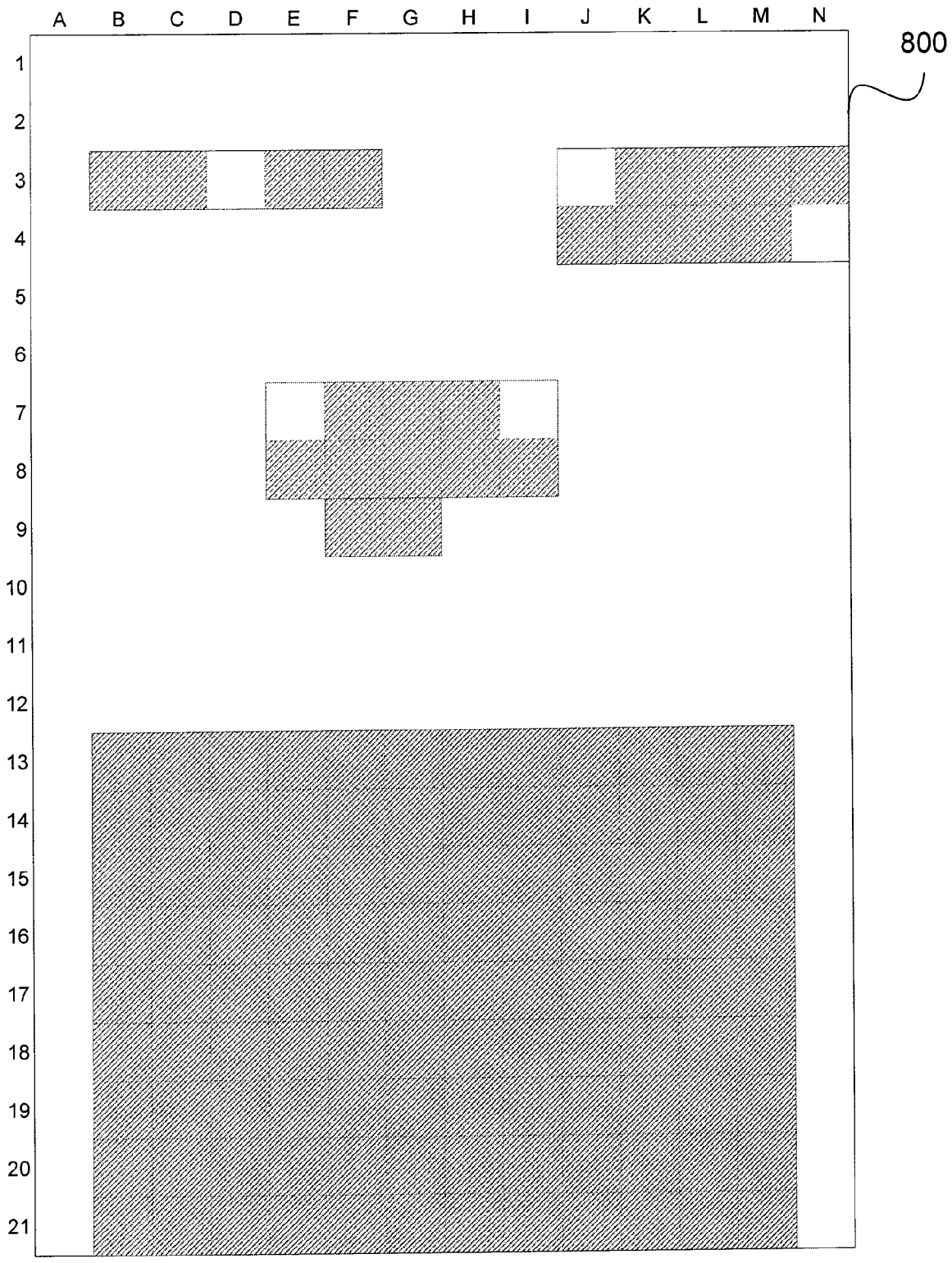

A B C D E F G H I J K L M N
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
800

Fig. 8C

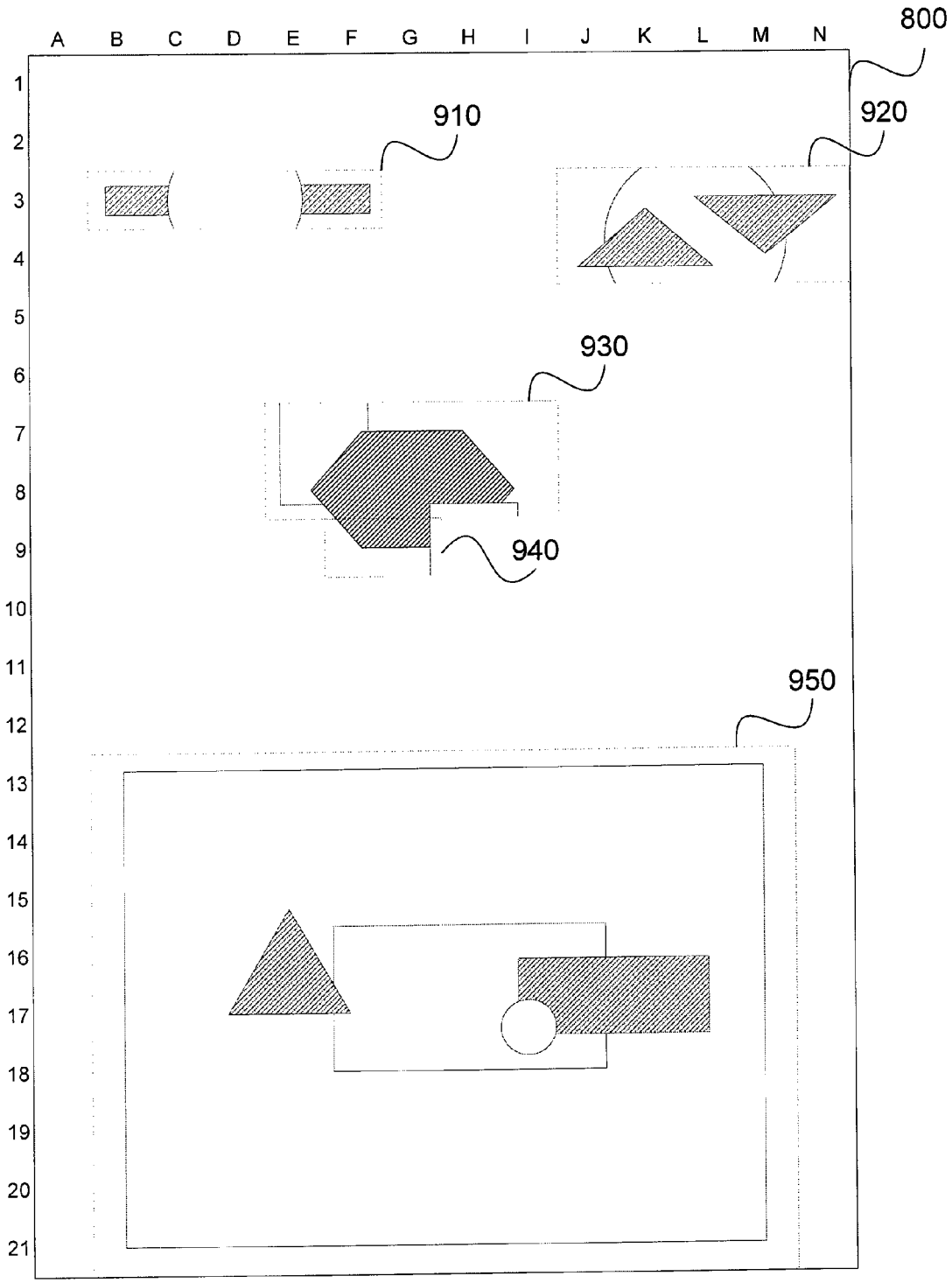

800
A B C D E F G H I J K L M N
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
910
920
930
940
950

Fig. 9

METHOD, APPARATUS AND SYSTEM FOR RENDERING AN OBJECT ON A PAGE

REFERENCE TO RELATED PATENT APPLICATION

This application claims priority under 35 U.S.C. §119 from Australian Patent Application No. 2011203173, filed Jun. 29, 2011, which is hereby incorporated by reference in its entirety as if fully set forth herein.

FIELD OF INVENTION

The current invention relates to graphics processing and, in particular, to a method and apparatus for rendering an object on a page. The current invention also relates to a computer program product including a computer readable medium having recorded thereon a computer program for rendering an object on a page.

DESCRIPTION OF BACKGROUND ART

The printing process in modern operating systems, typically involves steps of invoking drawing functions, converting the drawing functions into a standardized format (e.g. PDF or XPS), and spooling the standardized format drawing functions to a printer driver. The printer driver may contain an interpreter which parses the standardized format drawing functions, and converts the standardized format drawing functions into drawing instructions that are accepted by a printer driver rendering engine. The printer driver rendering engine typically renders the drawing instructions to pixels, and sends the pixels to a printer which prints the pixels onto paper.

Some printers have limited rendering functionality. A printer driver used by such printers may contain an interpreter that parse the standardized format into certain printer-recognizable graphical objects and drawing instructions that are accepted by the printer. The printer driver sends the generated graphical objects and drawing instructions to the printer. The printer then renders the graphical objects and drawing instructions into pixels.

Conventional methods for converting graphical objects and drawing instructions parsed from the standardized format into limited, printer-supported graphical objects, typically include processes for translating any printer-compatible graphical objects and drawing instructions directly into a printer-recognizable format. Such methods typically also include processes for rendering any printer-incompatible graphical objects and drawing instructions into pixels. The conventional methods for converting graphical objects and drawing instructions into limited, printer-supported graphical objects may result in a large amount of image data being sent to the printer, especially when there is lots of overlap between printer-compatible objects and printer-incompatible objects. The large amount of image data often results in a slow printing speed.

Thus, a need clearly exists for a better and more efficient printing method that will result in a faster printing speed.

SUMMARY OF THE INVENTION

It is an object of the present invention to substantially overcome, or at least ameliorate, one or more disadvantages of existing arrangements.

According to one aspect of the present disclosure there is provided a method of rendering a graphical object on a page, the method including:

marking a region of the page containing the graphical object as output incompatible based on the graphical object being output incompatible;

determining a bounding box including the marked region;

determining a proportion of a number of the regions marked as output incompatible to a total number of regions in the bounding box;

marking a further region within the bounding box as output incompatible to increase the determined proportion above a threshold;

converting the graphical object in the marked region and the further marked region into an output compatible graphical object if the determined proportion is above the threshold; and

rendering the output compatible graphical object.

According to another aspect of the present disclosure there is provided a method of rendering a graphical object on a page, the method including:

marking a first region of the page containing the graphical object as output incompatible based on the graphical object being output incompatible;

determining a distance of a second region from the first region;

marking the second region as output incompatible, if the determined distance satisfies a threshold;

converting graphical objects within the first and the second region as output compatible; and

rendering the output compatible objects.

According to still another aspect of the present disclosure there is provided a method of rendering a graphical object on a page, the method including:

determining a size of the graphical object to be rendered on the page;

marking a region of the page as output incompatible if (a) the graphical object is output incompatible, and (b) the determined size of the graphical object is larger than a threshold;

converting the graphical object into an output compatible graphical object; and

rendering the output compatible object to a renderer for rendering.

According to still another aspect of the present disclosure there is provided a system for rendering a graphical object on a page, the system including:

a memory for storing data and a computer program;

a processor coupled to the memory for executing the computer program, the computer program including instructions for:

marking a region of the page containing the graphical object as output incompatible based on the graphical object being output incompatible;

determining a bounding box including the marked region;

determining a proportion of a number of the regions marked as output incompatible to a total number of regions in the bounding box;

marking a further region within the bounding box as output incompatible to increase the determined proportion above a threshold;

converting the graphical objects in the marked region and the further marked region into an output compatible graphical object if the determined proportion is above the threshold; and

rendering the output compatible graphical object.

According to still another aspect of the present disclosure there is provided a system for rendering a graphical object on a page, the system including:

a memory for storing data and a computer program;

a processor coupled to the memory for executing the computer program, the computer program including instructions for:

marking a first region of the page containing the graphical object as output incompatible based on the graphical object being output incompatible;

determining a distance of a second region from the first region;

marking the second region as output incompatible, if the determined distance satisfies a threshold;

converting graphical objects within the first and the second region as output compatible; and

rendering the output compatible graphical objects.

According to still another aspect of the present disclosure there is provided an apparatus for rendering a graphical object on a page, the apparatus including:

means for marking a region of the page as output incompatible based on the mapped graphical object being output incompatible;

means for determining a bounding box including the marked region;

means for determining a proportion of a number of the regions marked as output incompatible to a total number of regions in the bounding box;

means for marking a further region within the bounding box as output incompatible to increase the determined proportion above a threshold;

means for converting the graphical object in the marked region and the further marked region into an output compatible graphical object if the determined proportion is above the threshold; and

means for rendering the output compatible graphical object.

According to still another aspect of the present disclosure there is provided an apparatus for rendering a graphical object on a page, the apparatus including:

means for marking a first region of the page containing the graphical object as output incompatible based on the graphical object being output incompatible;

means for determining a distance of a second region from the first region;

means for marking the second region as output incompatible, if the determined distance satisfies a threshold;

means for converting graphical objects within the first and the second region as output compatible; and

means for rendering the output compatible objects.

According to still another aspect of the present disclosure there is provided a computer readable medium having a computer program recorded thereon for rendering a graphical object on a page, the computer program including:

code for marking a region of the page containing the graphical object as output incompatible based on the graphical object being output incompatible;

code for determining a bounding box including the marked region;

code for determining a proportion of a number of the regions marked as output incompatible to a total number of regions in the bounding box;

code for marking a further region within the bounding box as output incompatible to increase the determined proportion above a threshold;

code for converting the graphical object in the marked region and the further marked region into an output compatible graphical object if the determined proportion is above the threshold; and

code for rendering the output compatible graphical object.

According to still another aspect of the present disclosure there is provided a computer readable medium having a computer program recorded thereon for rendering a graphical object on a page, the computer program including:

code for marking a first region of the page containing the graphical object as output incompatible based on the graphical object being output incompatible;

code for determining a distance of a second region from the first region;

code for marking the second region as output incompatible, if the determined distance satisfies a threshold;

code for converting graphical objects within the first and the second region as output compatible; and

code for rendering the output compatible objects.

Other aspects of the invention are also disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

One or more embodiments of the invention will now be described with reference to the following drawings, in which:

FIGS. **1**A and **1**B form a schematic block diagram of a general purpose computer system upon which arrangements described may be practiced;

FIG. **2** is a schematic flow diagram showing a method of rendering a graphical object on a page;

FIG. **3** is a schematic flow diagram showing a method of marking one or more regions of the page as output incompatible, as used in the method of FIG. **2**;

FIG. **4** is a schematic flow diagram showing a method of mapping a graphical object onto one or more corresponding regions of a page, as used in the method of FIG. **2**; and

FIG. **5** is a schematic flow diagram showing a method of converting regions marked as output incompatible to output compatible regions, as used in the method of FIG. **1**;

FIG. **6** is a schematic flow diagram showing a method of merging regions of the page to be printed into groups, as used in the method of FIG. **5**;

FIG. **7** is a schematic flow diagram showing a method of processing each row of regions to be merged, as used in the method of FIG. **6**;

FIG. **8**A shows an example page which contains several graphical objects to be printed;

FIG. **8**B shows the result of the example in FIG. **8**A, after the method of FIG. **7** has been performed on the page of FIG. **8**A;

FIG. **8**C shows the result of the example in FIG. **8**B, after the method of FIG. **6** has been performed on the page of FIG. **8**A; and

FIG. **9** shows the result of the example in FIG. **8**A, after the method of FIG. **5** has been performed on the page of FIG. **8**A.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Where reference is made in any one or more of the accompanying drawings to steps and/or features, which have the same reference numerals, those steps and/or features have for the purposes of this description the same function(s) or operation(s), unless the contrary intention appears.

A method **200** (see FIG. **2**) of rendering a graphical object on a page, is described below with reference to FIGS. **1**A to **9**. The method **200** takes into account a compatible/incompat-

ible property of the graphical object as well as other properties of the graphical object, such as object type and size as well as overlap.

FIGS. **1**A and **1**B depict a general-purpose computer system **100**, upon which the described methods, including the method **300**, may be practiced.

As seen in FIG. **1**A, the computer system **100** includes: a computer module **101**; input devices such as a keyboard **102**, a mouse pointer device **103**, a scanner **126**, a camera **127**, and a microphone **180**; and output devices including a printer **115**, a display device **114** and loudspeakers **117**. An external Modulator-Demodulator (Modem) transceiver device **116** may be used by the computer module **101** for communicating to and from a communications network **120** via a connection **121**. The communications network **120** may be a wide-area network (WAN), such as the Internet, a cellular telecommunications network, or a private WAN. Where the connection **121** is a telephone line, the modem **116** may be a traditional "dial-up" modem. Alternatively, where the connection **121** is a high capacity (e.g., cable) connection, the modem **116** may be a broadband modem. A wireless modem may also be used for wireless connection to the communications network **120**.

The computer module **101** typically includes at least one processor unit **105**, and a memory unit **106**. For example, the memory unit **106** may have semiconductor random access memory (RAM) and semiconductor read only memory (ROM). The computer module **101** also includes a number of input/output (I/O) interfaces including: an audio-video interface **107** that couples to the video display **114**, loudspeakers **117** and microphone **180**; an I/O interface **113** that couples to the keyboard **102**, mouse **103**, scanner **126**, camera **127** and optionally a joystick or other human interface device (not illustrated); and an interface **108** for the external modem **116** and printer **115**. In some implementations, the modem **116** may be incorporated within the computer module **101**, for example within the interface **108**. The computer module **101** also has a local network interface **111**, which permits coupling of the computer system **100** via a connection **123** to a local-area communications network **122**, known as a Local Area Network (LAN). As illustrated in FIG. **1**A, the local communications network **122** may also couple to the wide network **120** via a connection **124**, which would typically include a so-called "firewall" device or device of similar functionality. The local network interface **111** may comprise an Ethernet™ circuit card, a Bluetooth™ wireless arrangement or an IEEE 802.11 wireless arrangement; however, numerous other types of interfaces may be practiced for the interface **111**.

The I/O interfaces **108** and **113** may afford either or both of serial and parallel connectivity, the former typically being implemented according to the Universal Serial Bus (USB) standards and having corresponding USB connectors (not illustrated). Storage devices **109** are provided and typically include a hard disk drive (HDD) **110**. Other storage devices such as a floppy disk drive and a magnetic tape drive (not illustrated) may also be used. An optical disk drive **112** is typically provided to act as a non-volatile source of data. Portable memory devices, such optical disks (e.g., CD-ROM, DVD, Blu-ray Disc™), USB-RAM, portable, external hard drives, and floppy disks, for example, may be used as appropriate sources of data to the system **100**.

The components **105** to **113** of the computer module **101** typically communicate via an interconnected bus **104** and in a manner that results in a conventional mode of operation of the computer system **100** known to those in the relevant art. For example, the processor **105** is coupled to the system bus **104** using a connection **118**. Likewise, the memory **106** and optical disk drive **112** are coupled to the system bus **104** by connections **119**. Examples of computers on which the described arrangements can be practised include IBM-PC's and compatibles, Sun Sparcstations, Apple Mac™ or a like computer systems.

The described methods, including the method **200**, may be implemented using the computer system **100** wherein the processes of FIGS. **1** to **9**, to be described, may be implemented as one or more software application programs **133** executable within the computer system **100**. In particular, the steps of the described method **200** are effected by instructions **131** (see FIG. **1**B) in the software application program **133** that are carried out within the computer system **100**. The software instructions **131** may be formed as one or more software code modules, each for performing one or more particular tasks. The software application program **133** may also be divided into two separate parts, in which a first part and the corresponding software code modules performs the described methods and a second part and the corresponding software code modules manage a user interface between the first part and the user.

The software application program **133** may be stored in a computer readable medium, including the storage devices described below, for example. The software application program **133** is loaded into the computer system **100** from the computer readable medium, and is then executed by the computer system **100**. A computer readable medium having such software or computer program recorded on the computer readable medium is a computer program product. The use of the computer program product in the computer system **100** preferably effects an advantageous apparatus for implementing the described methods.

The software application program **133** is typically stored in the HDD **110** or the memory **106**. The software application program **133** is loaded into the computer system **100** from a computer readable medium, and executed by the computer system **100**. Thus, for example, the software application program **133** may be stored on an optically readable disk storage medium (e.g., CD-ROM) **125** that is read by the optical disk drive **112**.

In some instances, the software application program **133** may be supplied to the user encoded on one or more CD-ROMs **125** and read via the corresponding drive **112**, or alternatively may be read by the user from the networks **120** or **122**. Still further, the software application program **133** can also be loaded into the computer system **100** from other computer readable media. Computer readable storage media refers to any non-transitory tangible storage medium that provides recorded instructions and/or data to the computer system **100** for execution and/or processing. Examples of such storage media include floppy disks, magnetic tape, CD-ROM, DVD, Blu-ray Disc, a hard disk drive, a ROM or integrated circuit, USB memory, a magneto-optical disk, or a computer readable card such as a PCMCIA card and the like, whether or not such devices are internal or external of the computer module **101**. Examples of transitory or non-tangible computer readable transmission media that may also participate in the provision of software, application programs, instructions and/or data to the computer module **101** include radio or infra-red transmission channels as well as a network connection to another computer or networked device, and the Internet or Intranets including e-mail transmissions and information recorded on Websites and the like.

The second part of the software application program **133** and the corresponding software code modules mentioned above may be executed to implement one or more graphical user interfaces (GUIs) to be rendered or otherwise repre-

sented upon the display **114**. Through manipulation of typically the keyboard **102** and the mouse **103**, a user of the computer system **100** and the application may manipulate the interface in a functionally adaptable manner to provide controlling commands and/or input to the applications associated with the GUI(s). Other forms of functionally adaptable user interfaces may also be implemented, such as an audio interface utilizing speech prompts output via the loudspeakers **117** and user voice commands input via the microphone **180**.

FIG. **1**B is a detailed schematic block diagram of the processor **105** and a "memory" **134**. The memory **134** represents a logical aggregation of all the memory modules (including the HDD **109** and semiconductor memory **106**) that can be accessed by the computer module **101** in FIG. **1**A.

When the computer module **101** is initially powered up, a power-on self-test (POST) program **150** executes. The POST program **150** is typically stored in a ROM **149** of the semiconductor memory **106** of FIG. **1**A. A hardware device such as the ROM **149** storing software is sometimes referred to as firmware. The POST program **150** examines hardware within the computer module **101** to ensure proper functioning and typically checks the processor **105**, the memory **134** (**109**, **106**), and a basic input-output systems software (BIOS) module **151**, also typically stored in the ROM **149**, for correct operation. Once the POST program **150** has run successfully, the BIOS **151** activates the hard disk drive **110** of FIG. **1**A. Activation of the hard disk drive **110** causes a bootstrap loader program **152** that is resident on the hard disk drive **110** to execute via the processor **105**. This loads an operating system **153** into the RAM memory **106**, upon which the operating system **153** commences operation. The operating system **153** is a system level application, executable by the processor **105**, to fulfil various high level functions, including processor management, memory management, device management, storage management, software application interface, and generic user interface.

The operating system **153** manages the memory **134** (**109**, **106**) to ensure that each process or application running on the computer module **101** has sufficient memory in which to execute without colliding with memory allocated to another process. Furthermore, the different types of memory available in the system **100** of FIG. **1**A must be used properly so that each process can run effectively. Accordingly, the aggregated memory **134** is not intended to illustrate how particular segments of memory are allocated (unless otherwise stated), but rather to provide a general view of the memory accessible by the computer system **1100** and how such is used.

As shown in FIG. **1**B, the processor **105** includes a number of functional modules including a control unit **139**, an arithmetic logic unit (ALU) **140**, and a local or internal memory **148**, sometimes called a cache memory. The cache memory **148** typically includes a number of storage registers **144**-**146** in a register section. One or more internal busses **141** functionally interconnect these functional modules. The processor **105** typically also has one or more interfaces **142** for communicating with external devices via the system bus **104**, using a connection **118**. The memory **134** is coupled to the bus **104** using a connection **119**.

The software application program **133** includes a sequence of instructions **131** that may include conditional branch and loop instructions. The software application program **133** may also include data **132** which is used in execution of the program **133**. The instructions **131** and the data **132** are stored in memory locations **128**, **129**, **130** and **135**, **136**, **137**, respectively. Depending upon the relative size of the instructions **131** and the memory locations **128**-**130**, a particular instruction may be stored in a single memory location as depicted by the instruction shown in the memory location **130**. Alternately, an instruction may be segmented into a number of parts each of which is stored in a separate memory location, as depicted by the instruction segments shown in the memory locations **128** and **129**.

In general, the processor **105** is given a set of instructions which are executed therein. The processor **105** waits for a subsequent input, to which the processor **105** reacts to by executing another set of instructions. Each input may be provided from one or more of a number of sources, including data generated by one or more of the input devices **102**, **103**, data received from an external source across one of the networks **120**, **102**, data retrieved from one of the storage devices **106**, **109** or data retrieved from a storage medium **125** inserted into the corresponding reader **112**, all depicted in FIG. **1**A. The execution of a set of the instructions may in some cases result in output of data. Execution may also involve storing data or variables to the memory **134**.

The described methods use input variables **154**, which are stored in the memory **134** in corresponding memory locations **155**, **156**, **157**. The methods produce output variables **161**, which are stored in the memory **134** in corresponding memory locations **162**, **163**, **164**. Intermediate variables **158** may be stored in memory locations **159**, **160**, **166** and **167**.

Referring to the processor **105** of FIG. **1**B, the registers **144**, **145**, **146**, the arithmetic logic unit (ALU) **140**, and the control unit **139** work together to perform sequences of micro-operations needed to perform "fetch, decode, and execute" cycles for every instruction in the instruction set making up the program **133**. Each fetch, decode, and execute cycle comprises:

(a) a fetch operation, which fetches or reads an instruction **131** from a memory location **128**, **129**, **130**;

(b) a decode operation in which the control unit **139** determines which instruction has been fetched; and

(c) an execute operation in which the control unit **139** and/or the ALU **140** execute the instruction.

Thereafter, a further fetch, decode, and execute cycle for the next instruction may be executed. Similarly, a store cycle may be performed by which the control unit **139** stores or writes a value to a memory location **132**.

Each step or sub-process in the processes of FIGS. **1** to **9** is associated with one or more segments of the software application program **133** and is performed by the register section **144**, **145**, **147**, the ALU **140**, and the control unit **139** in the processor **105** working together to perform the fetch, decode, and execute cycles for every instruction in the instruction set for the noted segments of the software application program **133**.

The method **300** may alternatively be implemented in dedicated hardware such as one or more integrated circuits performing the functions or sub functions of the method **300**. Such dedicated hardware may include graphic processors, digital signal processors, or one or more microprocessors and associated memories.

The method **200** of rendering a graphical object on a page will now be described with reference to FIG. **2**. The method **200** may be implemented as one or more software code modules of the software application program **133** resident on the hard disk drive **110** and being controlled in its execution by the processor **105**.

The method **200** begins at drawing command receiving step **201**, where the processor **105** receives one or more drawing commands which may be stored in memory **106**. The drawing commands may be issued by another software application program resident on the hard disk drive **110** and being controlled by the processor **105**. Alternatively, the drawing

commands may be issued by a software application program resident on a remote server connected to the network **120**.

In one implementation, the drawing commands may be issued to an operating system spooler software module, using an operating system supplied graphics application programming interface. Such an operating system spooler software module may be resident on the hard disk drive **110** and be controlled in its execution by the processor **105**. At converting step **203**, the processor **105** (or the operating system spooler software module under execution of the processor **105**) converts the drawing commands to a standardized file format such as the XPS file format or the Portable Document Format (PDF).

Then, at interpreting step **205**, the standardized file format is interpreted into an intermediate graphical object. The intermediate graphical object contains corresponding drawing instructions of how to draw the graphical object onto the page, including graphics properties of the graphical object, such as shape, compositing method, clipping information and possibly a bounding box. In one implementation, step **205** may be executed by a printer driver software module resident on the hard disk drive **110** and being controlled in its execution by the processor **105**.

At storing step **207**, the intermediate graphical object and corresponding drawing instructions are stored in a self-retained display list (SRDL) configured within the memory **106**. The self-retained display list is an internal display list that is constructed and used for converting the intermediate graphical object into printer-recognizable format. In one implementation, step **207** and following steps **209** to **213** may be executed by an object converter software module resident in the hard disk drive **110** and being controlled in its execution by the processor **105**. As described below, in steps **207** to **213** the intermediate graphical objects are converted into printer-compatible graphical objects in printer-recognizable format.

Then at mapping step **209**, the processor **105** performs the step of mapping the intermediate graphical object onto one or more corresponding regions of the page. In performing the mapping at step **209**, the processor **105** determines which regions of the page are touched by the graphical object. A method **400** of mapping the intermediate graphical object onto one or more corresponding regions of the page, as executed at step **209**, will be described in detail below with reference to FIG. **4**.

At marking step **211**, the processor **105** performs the step of marking the corresponding regions of the page as output incompatible based on the mapped graphical object being output incompatible, and any surrounding regions being classified as output incompatible (i.e., associated with a corresponding output incompatible graphical object). In one implementation, the corresponding regions of the page are marked as output incompatible based on a determined size of the graphical object satisfying a threshold as described below.

Each region of the page has a bounding box and an associated "dirty status" flag. The dirty status flag is used for remarking the corresponding region so as to indicate if the graphical object corresponding to the region is output incompatible (i.e., dirty) and needs to be converted to output compatible in following step **213**. A method **300** of marking one or more regions of the page as output incompatible, as executed at step **211**, will be described below with reference to FIG. **3**.

Then at deciding step **212**, if the processor **105** determines that there is a further intermediate graphical object to be processed (e.g., the printer driver software module has interpreted a further intermediate graphical object in the standardized file format), then the method **200** returns to step **209** to process the further intermediate graphical object. Otherwise, the method **200** proceeds to converting step **213**. The further intermediate graphical object is stored in the self-retained display list (SRDL) configured within the memory **106**.

At converting step **213**, the processor **105** performs the step of converting the regions marked as output incompatible (i.e., as dirty) to output compatible regions. As described in detail below, at step **213**, the processor **105** processes the dirty status flags of the regions and converts the dirty regions into printer-compatible graphical objects. A method **500** of converting regions marked as output incompatible to output compatible regions, as executed at step **213**, will be described in detail below with reference to FIG. **5**.

At rendering step **215**, the processor **105** performs the step of rendering the graphical object on the page using any corresponding output compatible regions. In one implementation, the processor **105** may pass the printer-compatible graphical object, together with corresponding drawing instructions, to a rendering engine software module residing on the printer **115**. Such a rendering engine renders the printer-recognizable graphical object into pixels, and prints the pixels onto the page.

The method **400** of mapping the intermediate graphical object onto one or more corresponding regions of the page, as executed at step **209**, will now be described with reference to FIG. **4**. In the method **400**, an intermediate graphical object is mapped onto corresponding regions of the page. Each region has a bounding box and an associated dirty status flag as described above. The method **400** may be implemented as one or more software code modules of the software application program **133** resident on the hard disk drive **110** and being controlled in its execution by the processor **105**. As described above, in one implementation, the method **400** may be executed by the object converter software module.

At step **410**, the processor **105** receives a bounding box of the intermediate graphical object, if the bounding box is provided in graphics properties associated with the intermediate graphical object. If the bounding box is not provided with the graphical object, then the processor **105** determines a bounding box using shape and clipping information provided with graphics properties of the graphical object.

At step **420**, the processor **105** uses the bounding box of the graphical object to determine which regions of the page are touched by the graphical object. In particular, the processor **105** determines intersections between the bounding box of the graphical object and bounding boxes of each of the regions. If intersections are determined, then the region is determined to be touched by the graphical object.

At step **430**, the processor **105** stores details of the determined touched regions within the memory **106**.

The method **300** of marking one or more regions of the page as output incompatible, as executed at step **211** of the method **200**, will now be described below with reference to FIG. **3**. In the method **300**, the intermediate graphical objects parsed from standardised format and stored in the self-retained display list are converted to printer-compatible graphical objects. The page is divided into grids of a pre-determined size. Each grid is a region as described above.

The method **300** may be implemented as one or more software modules of the software application program **133** and being controlled in its execution by the processor **105**.

The method **300** begins at dirty region determining step **330**, where if the processor **105** determines that all the regions of the page that are touched by the intermediate graphical object have an associated "dirty" status flag, then the method **300** concludes. Otherwise, the method **300** proceeds to step **340**.

A region that is marked as "dirty" means that the graphical object corresponding to the region is output incompatible (i.e., the graphical object is not in a format recognizable to the printer **115**) and needs to be converted into a printer-compatible graphical object. If all the touched regions already have the dirty flag on, then the method **300** skips further processing of the intermediate graphical object.

At printer-compatible determining step **340**, the processor **105** checks all graphics properties of the received intermediate graphical object, including corresponding drawing instructions used to draw the graphical object onto the page, the compositing method and the clipping information. If the processor **105** determines at step **340** that there are any graphics properties of the graphical object that are not compatible with the printer-recognizable format used by the printer **115** (i.e., the graphical object is not printer compatible), then the current graphical object is considered as a printer-incompatible object and the method **300** proceeds to marking step **360**. Otherwise, the method **300** proceeds to step **350**.

At marking step **360**, the processor **105** performs the step of marking the touched regions by setting the dirty flag associated with each of the touched regions to be TRUE; and the processor **105** skips further processing of the current intermediate graphical object.

If all graphics properties of the current intermediate graphical object are printer-compatible at step **340**, then the current graphical object is classified as a printer-compatible object and the method **300** proceeds to image determining step **350**.

At image determining step **350**, if the processor **105** determines that the current intermediate graphical object is a larger than a pre-determined threshold, opaque image, that is not going to be scaled up too much on the page to be printed, then the method **300** proceeds to step **360**. Otherwise, the method **300** proceeds to storing step **370**.

A maximum threshold of scaling factor of the images, big_image_max_scaled_factor, and a minimum threshold of the image size, big_image_min_image_size, may be configured within the memory **106**. Accordingly, if the current graphical object is an opaque image that is larger than the big_image_min_image_size threshold and has a scaling factor less than the big_image_max_scaled_factor threshold, then all regions touched by the current graphical object are marked as dirty at step **360**.

At storing step **370**, the intermediate graphical object is stored within the memory **106** for printing by the rendering engine, for example, in a printer-recognizable format.

At step **375**, the processor **105** determines if there are any regions of the page that are fully covered by the current printer-compatible graphical object. Depending on the graphics properties of the graphical object, including the clipping information, if a region is fully covered by the graphical object then all previous contents in the region will not be shown on the printed page. The processor **105** marks such a region as output compatible at step **375** by setting the dirty status flag of such a region to FALSE. The method **300** concludes following step **375**.

The method **500** of converting regions, marked as output incompatible, to output compatible regions, will be described in detail below with reference to FIG. **5**. The method **500** processes the dirty status of all regions of the page, and converts the dirty regions into printer-compatible graphical objects.

The method **500** may be implemented as one or more software code modules of the software application program **133** resident on the hard disk drive **110** and being controlled in its execution by the processor **105**. As described above, in one implementation, the method **500** may be executed by the object converter software module.

The method **500** begins at bounding box determining step **501**, where the processor **105** performs the step of determining bounding boxes each comprising a plurality of regions marked as output incompatible (i.e., the dirty regions). In particular, the processor **105** processes the dirty regions, marked in accordance with the method **300**, and merges the dirty regions into groups of "region_sets". The groups of region_sets are stored within the memory **106**.

A method **600** of merging regions into groups of region_sets, as executed at step **501**, will be described below with reference to FIG. **6**. In the method **600**, the processor **105** scans regions horizontally, starting at a first row of dirty tiles. In particular, starting at a left-most dirty tile of the first row, the processor **105** attempts to merge an adjacent tile to the right of the left-most dirty tile. Merging of the tiles succeeds if the adjacent tile on the right is dirty. However, if the adjacent tile is not dirty, then the merging of the tiles may fail, depending on an area threshold as described below. The method **600** determines a set of one or more dirty tile regions for the first row. After completing processing of the first row of dirty tiles, the processor **105** horizontally scans and merges a second row of dirty tiles in a similar manner.

After completing processing of the second row of dirty tiles, the processor **105** attempts to merge the set of dirty tiles from the first and second rows, again applying an area threshold to determine whether or not to carry out the merge. The result of merging the set of dirty tiles from the first and second rows is a set of one or more dirty tile regions. Processing then continues in a similar manner for each subsequent row of dirty tiles. At completion of processing of each row, a set of dirty tile regions (i.e., a region_set) in the processed row is merged with a previous combined set of dirty tile regions.

In one implementation, the processor **105** attempts to merge the set of dirty tiles from the first and the second rows, by determining a distance between the first and the second rows. If the distance satisfies a predetermined distance threshold, the result of merging the set of dirty tiles is a set of one or more dirty tile regions. Processing then continues in a similar manner for each subsequent row of dirty tiles. At completion of processing of each row, a set of dirty tile regions (i.e., a region_set) in the processed row is merged with a previously combined set of dirty tile regions.

Each region_set contains a group of regions of the page that forms a rectangle shape, and a bounding box of a region_set is determined by co-ordinates, (start_x, start_y), of a top left region of the page, and co-ordinates, (end_x, end_y), of a bottom right region of the page. Each region_set also contains information of how many regions of the page in total the region_set contains (i.e., "num_total_regions") and out of which how many regions are dirty regions (i.e., "num_dirty_regions"). Accordingly, at step **501**, the processor **105** also performs the step of determining a proportion of the number of output incompatible regions to total number of regions in the bounding box for a corresponding region_set.

At accessing step **510**, the processor **105** accesses a region_set from the memory **106**. Then at rendering step **520**, the processor **105** renders an image representing an area indicated by the accessed region_set, using information stored in the self-retained display list configured within the memory **106**. As described above, the self-retained display list contains the intermediate graphical objects and corresponding drawing instructions. The rendered image of the region_set may be stored within the memory **106** and contains all graphical objects in the corresponding area.

At converting step **530**, the processor **105** converts the rendered image into the printer-recognizable format corresponding to the printer **115**. In one implementation, the printer-recognizable formatted image is output to the rendering engine software module as described above. Then at decision step **535**, if the processor **105** determines that there are more region_sets within memory **106** for processing, then the method **500** proceeds to step **510** to get a next region_set. Otherwise, the method **500** concludes.

The method **600** of merging regions into groups of region_sets, as executed at step **501**, will be described below with reference to FIG. **6**. The method **600** may be implemented as one or more software code modules of the software application program **133** resident on the hard disk drive **110** and being controlled in its execution by the processor **105**. As described above, in one implementation, the method **600** may be executed by the object converter software module.

As described in detail below, in the method **600**, the processor **105** marks at least one output compatible region in the particular bounding box for a region_set as output incompatible in order to increase the proportion of the number of the output incompatible regions to a total number of regions above a threshold (i.e, a predefined merge_threshold). Once the proportion of the number of regions marked as output incompatible reaches a threshold, the region in the bounding box is merged by processor **105**.

In another implementation, if a region_set is within a predefined distance from another region_set, then both the region_sets are merged.

In the method **600**, all dirty regions (ie., regions associated with a printer incompatible graphical object) marked in accordance with the method **300** are merged into a group of region_sets.

The method **600** begins at processing step **601**, where the processor **105** processes each row of the regions to form a group of region_sets. A method **700** of processing each row of regions, as executed at step **601**, will be described below with reference to FIG. **7**. In the following steps **610** to **690**, the dirty regions in each row are merged into a group of region_sets, where each region_set is also a shape of rectangle area. Each region_set also contains a group of regions including dirty and clean regions.

At first row accessing step **610**, the processor **105** accesses a first row of the region_sets stored in memory **106**. Then at decision step **615**, if the processor **105** determines that there are no more rows of the region_sets to be processed, then the method **600** concludes. Otherwise, the method **600** proceeds to next row accessing step **620**.

At further row accessing step **620**, the processor **105** accesses a second row of the region_sets. At scanning step **630**, after accessing a first_row and a second_row of the region_sets, the processor **105** scans from left to right, finding a candidate region_set from each row to form the first two candidate region_sets. As each region_set has a bounding box represented by the (start_x, start_y) co-ordinate and the (end_x, end_y) co-ordinate, the candidate region_set is determined based on the start_x co-ordinate of the region_set. The candidate region_set with the smallest start_x co-ordinate is selected for each row.

At merging step **640**, the processor **105** merges the two candidate region_sets from the first_row and second_row to form a merged region_set by executing the comparison step **650**. If the two region_sets are merged, the merged region_set is a new rectangle shape of regions. The new rectangle shape of regions has a bounding box determined by the (min_x, min_y) and (max_x, max_y) co-ordinates, where the min_x and min_y represents minimum X and minimum Y values, respectively, from the bounding boxes of the two candidate region_sets, and max_x and max_y represents maximum X and minimum Y values from the bounding boxes of the two candidate region_sets.

The merged region_set formed at step **640** contains all regions contained in the two candidate region_sets, as well as all the clean regions in between the two candidate region_sets to form a new rectangle shape of regions. The num_total_regions and num_dirty_regions, configured within the memory **106**, for the new rectangle shape are also updated.

As part of the merging step **640**, in comparing step **650**, if the processor **105** determines that the ratio of the "dirty region" (region marked as output incompatible) to the total number of regions is greater than or equal to a predefined threshold that initiates merging merge_threshold, then the method **600** proceeds to step **670**. Otherwise, the attempted merging is deemed to have failed and the method **600** proceeds to step **660**.

At merging step **670**, the merged region_set is stored within the memory **106** as one of two next candidate region_sets. At step **660**, the candidate region_set with the larger start_x co-ordinate is stored in memory **106** as one of two next candidate region_sets.

At determining step **680**, if the processor **105** finds the other next candidate region_set based on the start_x co-ordinate from the first_row and second_row of the region_sets stored in the memory **106**, then the method **600** returns to step **640** to repeat the attempted merging steps, until all region_sets from both the first_row and the second row are processed. Otherwise, the method **600** proceeds to step **690**. Again the region_set with the smallest start_x co-ordinate is selected at step **680**.

At step **690**, the processor **105** finishes processing all region_sets from the first_row and the second_row of region_sets. The result merged region_sets are stored within the memory **106** as a new row of region_sets, which will be the first_row of the next round of processing. Then the method **600** repeats the steps from step **620**, where a second_row of region_sets is selected and merged with the first_row of region_sets.

The method **700** of processing each row of regions, as executed at step **601**, will now be described with reference to FIG. **7**. The method **700** may be implemented as one or more software code modules of the software application program **133** resident on the hard disk drive **110** and being controlled in its execution by the processor **105**. As described above, in one implementation, the method **700** may be executed by the object converter software module.

The method **700** processes each row of regions of the page stored in the memory and merges the dirty regions in each row (i.e., as marked in accordance with the method **300**) into a group of region_sets.

The method **700** begins at determining step **710**, where a new row of unprocessed regions stored in the memory **106** is selected by the processor **105** as a current row. Otherwise, if the processor **105** determines at step **710** that all rows of the regions stored in the memory **106** are processed, then the method **700** concludes.

At scanning step **720**, the processor **105** scans the regions selected at step **710** for the current row from left to right. The processor **105** selects a first dirty region and all adjacent dirty regions following the first dirty region, and merges the first dirty region and all adjacent dirty regions into a merged region_set. The bounding box of the merged region_set is determined based on the (start_x, start_y) co-ordinate of the first dirty region and the (end_x, end_y) co-ordinate of the last adjacent dirty region. Both num_total_regions and num_

dirty_regions are equal to the total number of the adjacent dirty regions merged together at step **720**. The merged region_ set is stored in memory **106** as the first_candidate region_set.

At decision step **730**, if the processor **105** determines that all groups of adjacent dirty regions have been processed for the current row, then the method **700** proceeds to step **735**. Otherwise, the method **700** returns to step **710**.

At merging step **735**, the processor **105** merges a next group of adjacent dirty regions into a new region_set. The new region_set is stored in the memory **106** as the second_ candidate region_set. Then at step **740**, the processor **105** tries to merge the first_candidate and second_candidate region_ sets and all the clean regions in between the first_candidate and second_candidate region_sets. By merging the first_candidate and second_candidate region_sets, the merged region_ set is a new rectangle shape of regions whose bounding box is determined by the (min_x, min_y), (max_x, max_y) co-ordinates, where the min_x and min_y are the minimum X and Y value from the bounding boxes of the two candidate region_ sets, and max_x and max_y are the maximum X and Y value from the bounding boxes of the two candidate region_ sets.

The merged region_set formed at step **740** contains all regions that were contained in the first and second candidate region_sets, as well as all the clean regions in between the first and second candidate region_sets to form a new rectangle shape of regions. The num_dirty_regions of the merged region_set equals the num_dirty_regions of the first_candidate region_set plus the num_dirty_regions of the second_ candidate region_set. The num_total_regions of the merged region_set equals the num_total_regions of the first_candidate region set plus the num_total_regions of the second_candidate region_set plus the number of the clean regions in between the first_candidate region_set and the second_candidate region_set.

At decision step **750**, if the processor **105** determines that the ratio of number of "dirty region" (region marked as output incompatible) to the total number of regions in the merged region_set is greater than or equal to a predefined threshold that initiates merging merge_threshold then the method **700** proceeds to step **760**. Otherwise, the method **700** proceeds to step **770**.

In one implementation, at decision step **750**, if the processor **105** determines that the distance between the clean region and a region marked as dirty (containing output incompatible graphical objects) satisfies a predefined threshold (e.g., fifty (50) pixels), the clean region is marked as dirty as well. The marking of the clean region as a dirty region initiates the merging process in merging step **760**. Otherwise, the method **700** proceeds to step **770**.

At step **760**, the merged region_set is stored in the memory **106** as a new region_set in the current row as the first_candidate region_set. Otherwise, the second_candidate region_set is stored in the memory **106** as the first_candidate region_set of a next round at storing step **770**.

Following steps **760** and **770**, the method **700** returns to step **730** and processing steps are repeated from step **735**, until there are no more dirty regions to be found in the current row. The next row of regions are then processed from step **710** as described above. When all rows of regions are processed, the method **700** concludes as described above.

The methods described above will now be described further by way of example with reference to FIGS. **8**A to **9**. In accordance with the example, intermediate graphical objects **801**, **802**, **803**, **804**, **805**, **806**, **807**, **808**, **809**, **810**, **811**, **812**, **813** of the page **800** are converted to printer-compatible graphical objects in accordance with the described methods.

In the example of FIGS. **8**A to **9**, the objects **801**, **802**, **803**, **804**, **805**, **806**, **807**, **808**, **809**, **810**, **811**, **812**, **813** are the graphical objects in the intermediate format sent from the printer driver software module and stored in the self-retained display list as described above. The objects **801**, **802**, **803**, **804**, **805**, **806**, **807**, **808**, **809**, **810**, **811**, **812**, **813** are drawn on the page **800** in the same order as the objects **801**, **802**, **803**, **804**, **805**, **806**, **807**, **808**, **809**, **810**, **811**, **812**, **813** are numbered. For example, an object with a smaller number (e.g., the object **801**) is rendered on the page **800** below an object with a higher number (e.g., the object **802**). The objects (e.g., **801**, **802**) are rendered using a suitable compositing algorithm and the smaller numbered object (e.g., **801**) as compositing background. In the example of FIGS. **8**A to **9**:

- objects **801**, **804**, **805**, **807**, **811**, **812**, which are shaded in FIG. **8**A, are printer-incompatible graphical objects;
- All other graphical objects of the page **800** (i.e. object **802**, **803**, **806**, **808**, **809**, and **813**) are printer-compatible graphical objects which are also fully opaque;
- object **809** is a non-scaled image object that is larger than the predefined big_image_max_scaled_size with zero (0) scaling factor, which is less than the pre-defined big_image_max_scaled_factor; and
- all objects other than object **809** are not image objects.

In accordance with the described methods, the printer-compatible graphical objects are not necessarily fully opaque. However, the objects (i.e., object **802**, **803**, **806**, **808**, **809**, and **813**) in the example of FIG. **8**A are set as fully opaque for ease of explanation.

The page **800** has been assigned numbers and letters in both the X and Y co-ordinate direction for the purpose of naming the grided regions as presented in FIG. **8**A. Starting from the left top corner of the page **800**, the names of the regions are: r(**1**A), r(**1**B) . . . r(**1**N), r(**2**A), r(**2**B), . . . r(**21**N). An example of a region_set combined by regions r(**1**A), r(**1**B), r(**2**A), r(**2**B) is referred to as "rs(**1**A, **2**B)", with (num_total_regions==4 & num_dirty_regions==0).

The pre-defined merge_threshold in the example of FIGS. **8**A to **9** is set to 80%. Regions of the page **800** touched by each graphical object, as determined at step **209** of the method **200** (i.e., in accordance with the method **400**), are as follows:

Object **801**: r(**3**B), r(**3**C), r(**3**D), r(**3**E), r(**3**F);

Object **802**: r(**2**C), r(**2**D), r(**2**E), r(**3**C), r(**3**D), r(**3**E), r(**4**C), r(**4**D), r(**4**E);

Object **803**: r(**2**K), r(**2**L), r(**2**M), r(**3**J), r(**3**K), r(**3**L), r(**3**M), r(**4**J), r(**4**K), r(**4**L), r(**4**M), r(**5**K), r(**5**L), r(**5**M);

Object **804**: r(**3**K), r(**4**J), r(**4**K), r(**4**L);

Object **805**: r(**3**L), r(**3**M), r(**3**N), r(**4**M);

Object **806**: r(**6**E), r(**6**F), r(**7**E), r(**7**F), r(**8**E), r(**8**F);

Object **807**: r(**7**F), r(**7**G), r(**7**H), r(**8**E), r(**8**F), r(**8**G), r(**8**H), r(**8**I), r(**9**F), r(**9**G), r(**9**H);

Object **808**: r(**8**G), r(**8**H), r(**8**I), r(**9**G), r(**9**H), r(**9**I), r(**10**G), r(**10**H), r(**10**I), r(**11**G), r(**11**H), r(**11**I);

Object **809**: r(**13**B) to r(**13**M), r(**14**B) to r(**14**M), r(**15**B) to r(**15**M), r(**16**B) to r(**16**M), r(**17**B) to r(**17**M), r(**18**B) to r(**18**M), r(**19**B) to r(**19**M), r(**20**B) to r(**20**M), r(**21**B) to r(**21**M);

Object **810**: r(**16**F) to r(**16**J), r(**17**F) to r(**17**J), r(**18**F) to r(**18**J);

Object **811**: r(**15**E), r(**16**D), r(**16**E), r(**17**D), r(**17**E), r(**17**F);

Object **812**: r(**16**I) to r(**16**L), r(**17**I) to r(**17**L);

Object **813**: r(**17**H), r(**17**I), r(**18**H), r(**18**I);

At the beginning of the method **200**, the dirty status flag of each of the regions of the page **800** are set to FALSE. When the object **801** is received by the processor **105** at step **207** of

the method **200**, the touched regions determined at step **209** are r(**3**B), r(**3**C), r(**3**D), r(**3**E) and r(**3**F). Since object **801** is a printer-incompatible object, at step **211** of the method **200** (i.e., at step **360** of the method **300**), the dirty flags of regions r(**3**B), r(**3**C), r(**3**D), r(**3**E) and r(**3**F) are set to be TRUE.

Then at step **212** of the method **200**, the method **200** returns to step **209** to get the next intermediate graphical object from the self-retained display list (i.e., as sent from the printer driver software module).

When object **802** is received by the processor **105**, the touched regions determined at step **209** include region r(**3**D), which was set to be dirty in the processing of object **801**. At step **350** of the method **300**, since object **802** is not an image object, the method **300** proceeds to step **370** where the processor **105** stores the object **802** in printer-recognizable format in the memory **106** for printing by the rendering engine software module, for example. At step **375** of the method **300**, since object **802** is a fully opaque printer-compatible object, and region r(**3**D) is fully covered by object **802**, the processor **105** sets the dirty flag of region r(**3**D) back to be FALSE. Then the method **200** returns to step **209** to get the next intermediate graphical object from the self-retained display list (i.e., as sent from the printer driver software module).

When the object **803** is received by the processor **105**, since the object **803** is a non-image printer-compatible object, the processor **105** stores the object **803** in printer-recognizable format in the memory **106** (as at step **370**) for printing by the rendering engine software module. The method **200** then returns to step **209** to get a next intermediate graphical object from the self-retained display list (i.e., as sent from the printer driver).

When the object **804** and object **805** are received by the processor **105** at step **207** of the method **200**, the touched regions determined at step **209** are r(**3**K), r(**4**J), r(**4**K), r(**4**L), r(**3**L), r(**3**M), r(**3**N) and r(**4**M). Since object **801** is a printer-incompatible object, at step **211** of the method **200** (i.e., at step **360** of the method **300**), the dirty flags of the regions r(**3**K), r(**4**J), r(**4**K), r(**4**L), r(**3**L), r(**3**M), r(**3**N) and r(**4**M) are set to be TRUE. Then at step **212** of the method **200**, the method **200** returns to step **209** to get the next intermediate graphical object from the self-retained display list configured within the memory **106**.

When object **806** is received by the processor **105** at step **207** of the method **200**, since the object **806** is a non-image printer-compatible object, the processor **105** stores the object **806** at step **370** in printer-recognizable format in the memory **106** for printing by the rendering engine software module, for example. The dirty flags of the regions that are touched by object **806** are not changed. The method **200** then returns to step **209** to get the next intermediate graphical object from the self-retained display list configured in the memory **106**.

When the object **807** is received by the processor **105** at step **207** of the method **200**, the touched regions determined at step **209** are r(**7**F), r(**7**G), r(**7**H), r(**8**E), r(**8**F), r(**8**G), r(**8**H), r(**8**I), r(**9**F), r(**9**G) and r(**9**H). Since object **807** is a printer-incompatible object, at step **211** of the method **200** (i.e., at step **360** of the method **300**), the dirty flags of the regions r(**7**F), r(**7**G), r(**7**H), r(**8**E), r(**8**F), r(**8**G), r(**8**H), r(**8**I), r(**9**F), r(**9**G) and r(**9**H) are set to be TRUE. Then at step **212** of the method **200**, the method **200** returns to step **209** to get the next intermediate graphical object from the self-retained display list configured within the memory **106**.

When object **808** is received by the processor **105**, the touched regions determined at step **209** includes region r(**9**H), which was set to be dirty in the processing of object **807**. At step **350** of the method **300**, since object **802** is not an image object, the method **300** proceeds to step **370** where the processor **105** stores the object **808** in printer-recognizable format in the memory **106** for printing by the rendering engine software module, for example. At step **375** of the method **300**, since object **808** is a fully opaque printer-compatible object, and region r(**9**H) is fully covered by object **802**, the processor **105** sets the dirty flag of region r(**9**H) back to be FALSE. Then the method **200** returns to step **209** to get the next intermediate graphical object sent from the self-retained display list (i.e., as sent from the printer driver).

When object **809** is received by the processor **105** at step **207** of the method **200**, the touched regions determined at step **209** are r(**13**B) to r(**13**M), r(**14**B) to r(**14**M), r(**15**B) to r(**15**M), r(**16**B) to r(**16**M), r(**17**B) to r(**17**M), r(**18**B) to r(**18**M), r(**19**B) to r(**19**M), r(**20**B) to r(**20**M), r(**21**B) to r(**21**M). Since object **809** is a non-scaled printer-compatible image object that is larger than a predefined big_image_max_scaled_size with zero (0) scaling factor, the result of step **350** is TRUE (i.e., the 'yes' arrow is followed at step **350**). The method **300** then proceeds to step **360** and sets dirty status flag of the regions touched by object **809** to be TRUE, without storing the object **809** in memory **106** for subsequent rendering by the rendering engine software module, even though the object **809** is printer-compatible. Then at step **212** of the method **200**, the method **200** returns to step **209** to get the next intermediate graphical object from the self-retained display list configured within the memory **106**.

When objects **810**, **811**, **812** and **813** are received by the processor **105** at step **207**, since the dirty status flags of the touched regions that are determined at step **209** are all already set to TRUE during processing object **809**, the results of step **330** of the method **300** are always TRUE for the process of processing objects **810**, **811**, **812** and **813**. The method **300** skips any further processing and the method **200** returns to step **209** to get the next intermediate graphical object from the self-retained display list configured within the memory **106**. Since there are no more objects on the page **800** to be processed at step **212**, the method **200** proceeds to step **213** where any regions marked as output incompatible are converted to output compatible regions. At this stage of the example, the dirty status of the regions on the page **800** is as shown in FIG. **8**B. In accordance with the example of FIGS. **8**A to **9**, below is a list of the dirty regions from each row of the page **800**:

Row **3**: r(**3**B), r(**3**C), r(**3**E), r(**3**F), r(**3**K), r(**3**L), r(**3**M), r(**3**N);

Row **4**: r(**4**J), r(**4**K), r(**4**L), r(**4**M);

Row **7**: r(**7**F), r(**7**G), r(**7**H);

Row **8**: r(**8**E), r(**8**F), r(**8**G), r(**8**H), r(**8**I);

Row **9**: r(**9**F), r(**9**G);

Row **13**: r(**13**B) to r(**13**M);

Row **14**: r(**14**B) to r(**14**M);

Row **15**: r(**15**B) to r(**15**M);

Row **16**: r(**16**B) to r(**16**M);

Row **17**: r(**17**B) to r(**17**M);

Row **18**: r(**18**B) to r(**18**M);

Row **19**: r(**19**B) to r(**19**M);

Row **20**: r(**20**B) to r(**20**M);

Row **21**: r(**21**B) to r(**21**M);

At step **501** of the method **500**, the processor **105** first executes the method **600** to merge the dirty regions of the page **800** shown in FIG. **8**B to form region_sets.

At step **601** of the method **600**, the processor **105** first executes the method **700** to process each row of the regions of the page **800**.

At step **710**, the processor **105** first gets Row **3** of the regions of the page **800**. At step **720**, the processor **105** merges regions r(**3**B) and r(**3**C) to region_set rs(**3**B, **3**C) with (num_total_regions==2; num_dirty_regions==2).

At step **730**, the processor **105** merges regions r(**3**E) and r(**3**F) to region_set rs(**3**E, **3**F) with (num_total_regions==2; num_dirty_regions==2).

At steps **740** and **750**, the processor **105** tries to merge the region_sets rs(**3**B, **3**C) and rs(**3**E, **3**F) to be rs(**3**B, **3**F) with (num_total_regions==5; num_dirty_regions==4). Since (num_dirty_regions/num_total_regions)==0.8>=merge_threshold (80%), the processor **105** goes to step **760** and stores the rs(**3**B, **3**F) in the memory **106** to be the new region_set for the current row.

At step **730**, the processor **105** merges regions r(**3**K), r(**3**L), r(**3**M) and r(**3**N) to region_set rs(**3**K, **3**N) with (num_total_regions==4; num_dirty_regions==4). At step **740** and **750**, the processor **105** tries to merge the region_sets rs(**3**B, **3**F) and rs(**3**K, **3**N) to be rs(**3**B, **3**N) with (num_total_regions==13; num_dirty_regions==8). Since (num_dirty_regions/num_total_regions)~=0.61<merge_threshold (80%), the method **700** proceeds to step **770**, does not merge the two candidate region_sets, and uses the rs(**3**K, **3**N) as the next candidate region_set.

At step **730**, since there are no more dirty regions on the current row, the method **700** proceeds to step **710** and accesses Row **4** of the regions. At this stage, the result region_sets for Row **3** are: rs(**3**B, **3**F), rs(**3**K, **3**N).

When Row **4** of the regions of page **800** are processed in accordance with the method **700**, since there is only one group of adjacent dirty regions on the current row, the result region_sets for Row **4** are: rs(**4**J, **4**M).

Similar to Row **4**, after the other rows of the regions of page **800** have been processed, the result region_sets for page **800** are as follows:

Row **3**: rs(**3**B, **3**F), rs(**3**K, **3**N);
Row **4**: rs(**4**J, **4**M);
Row **7**: rs(**7**F, **7**H);
Row **8**: rs(**8**E, **8**I);
Row **9**: rs(**9**F, **9**G);
Row **13**: rs(**13**B, **13**M);
Row **14**: rs(**14**B, **14**M);
Row **15**: rs(**15**B, **15**M);
Row **16**: rs(**16**B, **16**M);
Row **17**: rs(**17**B, **17**M);
Row **18**: rs(**18**B, **18**M);
Row **19**: rs(**19**B, **19**M);
Row **20**: rs(**20**B, **20**M);
Row **21**: rs(**21**B, **21**M);

After the last row Row **21** of the page **800** is processed in accordance with the method **700**, the method **600** proceeds to step **610** to get the region_sets from Row **3**, and then gets the region_sets from Row **4** at step **620**. At step **630**, the processor **105** gets region_sets rs(**3**B, **3**F) from Row **3** and rs(**4**J, **4**M) from Row **4** as two candidate region_sets to be merged.

At step **640** and **650** of the method **600**, the processor **105** tries to merge the two candidate region_sets rs(**3**B, **3**F) and rs(**4**J, **4**M) to be rs(**3**B, **4**M) with (num_total_regions==**24**; num_dirty_regions==11). Since (num_dirty_regions/num_total_regions)~=0.46<merge_threshold (80%), the method **600** proceeds to step **660**, does not merge the two candidate region_sets, and scans from left to right, drops region_set rs(**3**B, **3**F), and gets the region_set rs(**3**K, **3**N) as the next candidate region_set.

At steps **640** and **650**, the processor **105** tries to merge the two candidate region_sets rs(**3**K, **3**N) and rs(**4**J, **4**M) to be rs(**3**J, **4**N) with (num_total_regions==10; num_dirty_regions==8). Because (num_dirty_regions/num_total_regions)~=0.8>=merge_threshold (80%), the method **600** proceeds to step **670**, merges the two candidate region_sets to be the new candidate region_set, and proceeds to step **680** to find the next unprocessed region_set from Row **3** and Row **4** of the page **800**. Since there are no more region_sets on rows Row **3** and Row **4**, the method **600** goes to step **690** where the processor **105** merges the region_sets from Row **3** and Row **4** to one row as:

Row **3**: rs(**3**B, **3**F), rs(**3**J, **4**N);

The method **600** then returns to step **620** to get region_sets on Row **7** as the next row to be merged with the new Row **3** described above. At step **640** and **650**, the processor **105** tries to merge the two candidate region_sets rs(**3**B, **3**F) and rs(**7**F, **7**H) to be rs(**3**B, **7**H) with (num_total_regions==**40**; num_dirty_regions==7). Since (num_dirty_regions/num_total_regions)~=0.18<merge_threshold (80%), the processor **105** does not merge the two candidate region_sets, goes to step **660** and gets the next candidate region_set rs(**3**J, **4**N). Similarly, since the (num_dirty_regions/num_total_regions) is less than the merge_threshold 80%, the processor **105** does not merge the candidate region_sets rs(**7**F, **7**H) and rs(**3**J, **4**N). At step **680**, since there are no more unprocessed region_sets left on Row **3** and Row **7**, the method **600** proceeds to step **690**. Since there are no merged region_sets, result of the merging is still as follows:

Row **3**: rs(**3**B, **3**F), rs(**3**J, **4**N);
Row **7**: rs(**7**F, **7**H);

The method **600** then returns to step **620** to get region_sets on Row **8** as the next row to be merged with the Row **7**. At steps **640** and **650**, the processor **105** tries to merge the two candidate region_sets rs(**7**F, **7**H) and rs(**8**E, **8**I) to be rs(**7**E, **8**I) with (num_total_regions==10; num_dirty_regions==8). Since (num_dirty_regions/num_total_regions)=0.8>=merge_threshold (80%), the method **600** proceeds to step **670**, then to step **690** with the result of the new Row **7** as:

Row **7**: rs (**7**E, **8**I);

The method **600** then returns to step **620** to get region_sets on Row **9** as the next row to be merged with the new Row **7** as described above. At steps **640** and **650**, the processor **105** tries to merge the two candidate region_sets rs(**7**E, **8**I) and rs(**9**F, **9**G) to be rs(**7**E, **9**I) with (num_total_regions==15; num_dirty_regions==10). Since (num_dirty_regions/num_total_regions)~=0.67<merge_threshold (80%), the method **600** proceeds to step **660** and does not merge the two candidate region_sets. At step **690**, since there are no merged region_sets, the result of the merging is still as follows:

Row **7**: rs (**7**E, **8**I);
Row **9**: rs (**9**F, **9**G);

The method **600** then returns to step **620** to get region_sets on Row **13** as the next row to be merged with the Row **9** described above. At step **640** and **650**, the processor **105** tries to merge the two candidate region_sets rs(**9**F, **9**G) and rs(**13**B, **13**M) to be rs(**9**B, **13**M) with (num_total_regions==60; num_dirty_regions==14). Because (num_dirty_regions/num_total_regions)~=0.23<merge_threshold (80%), the method **600** proceeds to step **660**, does not merge the two candidate region_sets. At step **690**, since there are no merged region_sets, the result of the merging is still as follows:

Row **9**: rs (**9**F, **9**G);
Row **13**: rs (**13**B, **13**M);

The method **600** then returns to step **620** to get region_sets on Row **14** as the next row to be merged with the Row **13** described above. At step **640** and **650**, the processor **105** tries to merge the two candidate region_sets rs(**13**B, **13**M) and rs(**14**B, **14**M) to be rs(**13**B, **14**M) with (num_total_regions==24; num_dirty_regions==24). Since (num_dirty_regions/num_total_regions)=1>=merge_threshold (80%), the method **600** proceeds to step **670** then **690** with the result of the new Row **13** as follows:

Row **13**: rs (**13**B, **14**M);

Similarly, after processing the last row Row **21** of region_sets, the processor **105** merges all region_sets from Row **13** to Row **21** to be a new Row **13** as follows:

Row **13**: rs (**13**B, **21**M);

At step **620**, since there are no new rows to be processed, the processor **105** proceeds to step **510**. The final result from method **600** is as shown in FIG. **8**C. Below is a list of the merged region_sets to be output after the method **600**.

Row **3**: rs(**3**B, **3**F), rs(**3**J, **4**N);

Row **7**: rs (**7**E, **8**I);

Row **9**: rs(**9**F, **9**G);

Row **13**: rs(**13**B, **21**M);

In another implementation, instead of checking the (num_dirty_regions/num_total_regions) against a predefined threshold, the distance between a dirty region and a clean region is checked against a predetermined distance threshold. If the distance between the dirty candidate region_set and the clean candidate region_set is smaller than the predetermined threshold, then the dirty region and clean region are merged into one region_set.

FIG. **9** shows the output of the example of FIGS. **8**A and **8**B from the method **500**. At step **510**, the processor **105** accesses region_set rs(**3**B, **3**F) stored in the memory **106**; renders the self-retained display list (SRDL) of the area included in the bounding box of the region_set to an Image **910** at step **520**, then outputs the Image **910** to the printing engine software module in printer-recognizable format as at step **530**. The method **500** then repeats the steps from step **510**, accessing the region_set rs(**3**J, **4**N) stored in the memory **106**, rendering and outputting as Image **920**; then accessing the region_set rs(**7**E, **8**I) from the memory **106**, renders and outputs as Image **930**; then accesses the region_set rs(**9**F, **9**G), renders and outputs as Image **940**; and accesses the region_set rs(**13**B, **21**M), renders and outputs as Image **950**. After all region_sets are rendered and output to the rendering engine software module, the method **200** concludes.

INDUSTRIAL APPLICABILITY

The arrangements described are applicable to the computer and data processing industries and particularly for the image processing.

The foregoing describes only some embodiments of the present invention, and modifications and/or changes can be made thereto without departing from the scope and spirit of the invention, the embodiments being illustrative and not restrictive.

In the context of this specification, the word "comprising" means "including principally but not necessarily solely" or "having" or "including", and not "consisting only of". Variations of the word "comprising", such as "comprise" and "comprises" have correspondingly varied meanings.

The claims defining the invention are as follows:

1. A method of rendering graphical objects on a page, the method comprising:

marking a region of the page containing a graphical object as output incompatible based on the graphical object being output incompatible;

determining a bounding box comprising the marked region and at least one output compatible region, the output compatible region containing at least a portion of an output compatible graphical object;

determining a proportion of a number of the regions marked as output incompatible to a total number of regions in the bounding box;

marking said at least one output compatible region within the bounding box as output incompatible if the determined proportion is above a threshold;

converting the graphical objects in the marked output incompatible region into an output compatible graphical object; and

rendering the output compatible graphical object.

2. A system for rendering graphical objects on a page, the system comprising:

a memory for storing data and a computer program;

a processor coupled to the memory for executing the computer program, the computer program comprising instructions for:

marking a region of the page containing a graphical object as output incompatible based on the graphical object being output incompatible;

determining a bounding box comprising the marked region and at least one output compatible region, the output compatible region containing at least a portion of an output compatible graphical object;

determining a proportion of a number of the regions marked as output incompatible to a total number of regions in the bounding box;

marking said at least one output compatible region within the bounding box as output incompatible if the determined proportion is above a threshold;

converting the graphical objects in the marked output incompatible regions into an output compatible graphical object; and

rendering the output compatible graphical object.

3. An apparatus for rendering graphical objects on a page, the apparatus comprising:

means for marking a region of the page containing a graphical object as output incompatible based on the graphical object being output incompatible;

means for determining a bounding box comprising the marked region and at least one output compatible region, the output compatible region containing at least a portion of an output compatible graphical object;

means for determining a proportion of a number of the regions marked as output incompatible to a total number of regions in the bounding box;

means for marking said at least one output compatible region within the bounding box as output incompatible if the determined proportion is above a threshold;

means for converting the graphical object in the marked output incompatible regions into an output compatible graphical object; and

means for rendering the output compatible graphical object.

4. A non-transitory computer readable medium having a computer program recorded thereon for rendering graphical objects on a page, the computer program comprising:

code for marking a region of the page containing a graphical object as output incompatible based on the graphical object being output incompatible;

code for determining a bounding box comprising the marked region and at least one output compatible region, the output compatible region containing at least a portion of an output compatible graphical object;

code for determining a proportion of a number of the regions marked as output incompatible to a total number of regions in the bounding box;

code for marking said at least one output compatible region within the bounding box as output incompatible if the determined proportion is above a threshold;

code for converting the graphical objects in the marked output compatible regions into an output compatible graphical object; and

code for rendering the output compatible graphical object.

* * * * *